GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION

PROJECT INITIATION

Date: August 26, 1975

Project Title: Study to Investigate Potential Benefits from Synergistic Co-Siting of Industrial Activities

Project No.: A-1772

Project Director: Dr. Jack M. Spurlock

Sponsor: Appalachian Regional Commission, Washington, D. C.

Agreement Period: From August 1, 1975 Until June 30, 1976

Type Agreement: Grant No. GA-4234-75-I-302-0509

Amount: $74,991

Reports Required: Quarterly Progress; Final Technical

Sponsor Contact Person:
Mr. Michael A. Potterf
Project Coordinator
Room 627
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Washington, D. C. 20235
(202) 967-3671

Assigned to: Energy & Materials Technology Division

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Other Sue Corbin; Bonnee Wettlaufer

RA-3 (8-75)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 11/17/76

Project Title: Study to Investigate Potential Benefits from Synergistic Co-Siting of Industrial Activities.

Project No: A-1772

Project Director: Dr. J. M. Spurlock

Sponsor: Appalachian Regional Commission, Washington, D. C.

Effective Termination Date: 9/30/76

Clearance of Accounting Charges: 10/31/76

Grant/Contract Closeout Actions Remaining:

- x Final Invoice and Closing Documents
- _ Final Fiscal Report
- x Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other _____

Assigned to: Applied Sciences Laboratory (School/Laboratory)

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CA–4 (3/76)

A-1772

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 10, 1975

Appalachian Regional Commission
1666 Connecticut Avenue, N.W.
Washington, D.C. 20235

Attention: Mr. Michael A. Potterf
Room 627

Reference: ARC Grant No. GA-4234-75-I-302-0509
(Georgia Tech Project No. A-1772)

Subject: Quarterly Progress Report No. 1
"Study to Investigate Potential Benefits from Synergistic Co-siting of Industrial Activities"

Gentlemen:

This report summarizes progress on the referenced grant project for the period August 1 through October 31, 1975.

I. Introduction

The purpose of this program is to elucidate and evaluate the potential role of synergistic co-siting (i.e., mutually beneficial location and coupling of the input and output streams) of industrial plants, and other related activities, in the forming of policies and options for energy conservation, improvement of the environment, effective land use, and economic development of appropriate regions of the State of Georgia (primary emphasis) and the Appalachian Region. Anticipated results of this study include guidelines and recommendations for the practical application of co-siting in these regions, and the effective communication of the information to prospective users who are likely to be involved in planning and implementing the appropriate applicational activities.

The specific objectives of the program are:

(1) the identification and classification of technical factors that have the greatest influence on the selection of co-siting groupings;

(2) the screening and selection of co-siting grouping possibilities that offer significant promise for providing important resource-utilization benefits (in Georgia's Appalachian areas specifically, as well as in the Appalachian Region generally);

(3) the economic evaluation of the selected co-siting grouping examples to establish cost-benefit comparisons between conventional and co-siting methods of industrial operations;

(4) the formulation, documentation and communication of recommendations and guidelines for --

- specific co-siting groupings that show very promising prospects as experimental prototypes, for selected regions of application, to demonstrate the benefits of synergistic co-siting methodology;
- use of the methodology developed on this program as an important new tool for industrial development activities in other locations of the Appalachian Region, etc.;
- further technology developments, policy analysis, etc., that will be required to broaden the potential scope of application of synergistic co-siting and provide the necessary incentives and stimulation for implementational initiatives by prospective users.

To meet these objectives, the following tasks constitute the overall work plan for the program:

Task I -- Data-base Development;

Task II -- Preliminary Search for Co-siting Candidates;

Task III -- Preliminary Chemical Engineering (Feasibility) Analysis for Candidates;

Task IV -- Development of Economic Model and Scaling Relationship;

Task V -- Selection of Technically Feasible Co-siting Groupings;

Task VI -- Economic Evaluation of Technically Feasible Groupings;

Task VII -- Regional Application Analysis;

Task VIII -- Formulate Recommendations and Conclusions;

Task IX -- Initiate Utilization Plan;

Task X -- Prepare and Distribute Final Report.

II. Project Schedule and Budget Status

The project effort is currently on schedule and operating within the budget plan. During the first week of the program, the schedule plan was revised somewhat from the plan presented in the original proposal for this grant. These revisions were structured to provide a better coupling of certain task efforts and a significantly earlier (and more timely) initiation of communication of project goals, methods and results to prospective users (i.e., government and industrial planners); the latter is a component of the Utilization Plan, Task IX. These revisions were coordinated with and approved in advance by Mr. Michael Potterf of the Appalachian Regional Commission. The revised schedule plan is shown in Figure 1. On this figure, progress status is represented by the placement of a solid triangle on the time-line for each task that has been started thus far on the program. The location of the triangle represents the approximate degree of completion of that task (e.g., a triangle at about the mid-point of the task time-line indicates that the task effort is about 50 percent completed; a triangle at the end of the line denotes completion of the effort on that task). Milestones for project deliverables (reports, etc.) are represented by arrowheads; open arrowheads denote milestones that have not yet been accomplished, and solid symbols denote completed milestones.

Budget status is as follows:

(1)	Total Expenditures to Date:	$11,652
(2)	Expenditures by Categories:	
	(a) Direct Personal Services --	$ 6,700
	(b) Materials and Supplies --	$ 61
	(c) Travel --	$ 62
	(d) Computer Services --	-0-
	(e) Overhead & Benefits --	$ 4,829
(3)	Total Grant Funds Remaining:	$63,339

III. Technical Progress to Date

Technical progress during the first quarterly reporting period of the project is summarized below, by tasks, for those task items that were scheduled for activity according to the schedule plan shown in Figure 1.

Overall Progress Summary --

Effort was initiated on Tasks I, II, III, IV, V, VII and IX (described in Section I of this report). All of these efforts are on schedule and are providing the anticipated results to date. Tasks I, II, III and V are providing the information and basis required for the selection of several technically feasible candidate co-siting groupings; in addition, these tasks are producing a general methodology for such a preliminary selection process. Task IV is providing part of the basis for a cost-benefit evaluation of the technically feasible candidate groupings. Task VII is providing a basis for the selection of specific candidate co-siting groupings that are applicable to the North Georgia Area Planning and Development Region, the selected prototype applicational siting region for this program. Task IX is providing the planning and presentation material for programmed seminars or briefing conferences and workshops which will be conducted on this project to communicate the background information on the synergistic co-siting concept, interim results and general methodology (developed on the project) to invited participants, representing potential users of this information, in an effective and timely manner.

Task I. Data-base Development --

A broad spectrum of pertinent data has been collected and compiled, including primary and secondary literature items on industrial plant siting technology; recent marketing and economic data and indicators for important industrial products; flowsheets, material and energy balances, and production technology for important industrial chemical processes; etc. This information is being screened and

developed into a reference bibliography for the project. This data-base serves as the information foundation for the entire project.

Task II. Preliminary Search for Co-siting Candidates --

A large number and wide variety of industrial processes and activities have been screened, based upon the data provided by Task I. Screening criteria were developed and are being used to evaluate the technical- and economic-viability potential for these processes in a co-siting mode of operation. The criteria are based principally on the relative potential benefit that each process could provide or receive in a co-siting grouping, its economic growth potential over a reasonable and predictable period of time, and its potential versatility of application in a number of different co-siting grouping options. Examples of some of the industrial processes and activities that have been preliminarily selected, thus far, for further evaluation include: waste processing (pyrolysis); stack-gas effluent-removal processes; waste-water treatment processes; fertilizer chemical processes; processes which use large quantities of coal (e.g., fossil-fuel power plants, energy-intensive industrial processes, coal-conversion processes, etc.); and several of the more economically important primary and intermediate inorganic and organic chemical manufacturing processes (e.g., sulfuric acid, chlorine, ethylene, methane, ethyl and methyl alcohol, etc.). The search effort is still in progress.

Task III. Preliminary Chemical Engineering Analysis for Candidates --

This task effort is strongly coupled to the efforts on Tasks I and II. The candidate individual processes selected on Task II for further evaluation are being assessed for co-siting grouping roles. Initially, sets of paired processes and/or activities are being studied for feasibility and potential synergism. Subsequently, groupings consisting of larger numbers of component processes/activities will be identified and evaluated. The analysis consists principally of developing input/

output (raw materials and products, energy requirements and excesses, and by-products and wastes) matrices for several of the candidate processes and activities selected on Task II, using flowsheet, material balance and energy balance information obtained on Task I. From this matrix display of process input and output data, processes are identified which have a significant degree of matching potential among their input and output streams, and fundamental technical compatibility that would facilitate the possible coupling of some of these streams. This effort is approximately 50 percent completed and is continuing. Most of the effort to date has involved the development of the input/output matrix format and analysis methodology.

Task IV. Scaling Relationships for Plant Economics --

Effort on this task was just recently initiated, and was dependent upon the availability of some of the data from the Task I effort. Results of Task IV will provide a basis for determining the effects of plant size and capacity on the economic characteristics of selected candidate groupings. These results will support the econnomic evaluation effort on Task VI. Several sources of information relating to scaling criteria and techniques have been obtained on Task I and are being examined for validity, consistency and agreement. A large number of important processes of interest on this program are covered by the information compiled thus far. It is anticipated that the computer analysis procedure can be adapted from existing plant-costing programs currently being used at Georgia Tech.

Task V. Selection of Technically Feasible Co-siting Groupings --

Effort on this task also was just recently initiated and is continuing. Inputs to this effort include the results being derived from Tasks I, II, and III, described above. In particular, process-grouping candidates identified on Task III as having especially strong potential for matching of their input and/or output streams (to provide some important synergistic benefits), as well as apparent

technical compatibility, are being studied in detail regarding several key factors. These factors include: (1) capacity compatibility (i.e., the raw-material or energy requirements of one process, in the capacity range necessary to justify its operations, can be met by the by-product or waste outputs of another process operating in its optimum range of capacity); (2) technological developments or design changes required to achieve effective and efficient coupling; and (3) other operational interfacing requirements and potential problems of coupling. Once these factors have been studied, those candidate groupings which still offer signficant promise are characterized in a co-siting configuration by detailed flowsheets, material balances and energy balances to the extent that reliable data are available from Task I. These configurations are carefully analyzed again for design and operational feasibility and the auspicious ones are then ready for in-depth economic-viability analysis on Task VI. The methodology for this procedure is still being developed and will be applied (and refined as necessary) as candidate groupings become available from the Task III effort.

Task VII. Regional Application Analysis --

The project team has met with principal representatives of the North Georgia Area Planning and Development Commission (in Dalton, GA) and visited industrial plant sites in that area. From this activity important information has been obtained concerning specific problems associated with (1) the operations of present industry in that Appalachian region, and (2) the attracting of new, compatible industry into the region. This information is being assessed to provide the basis for the selection of specific example co-siting applications that would contribute to the solution of the problems and provide benefits through synergistic coupling of industrial activities (existing activities as well as promising new activities). One example application now under study in detail (using the methodology that is being developed on Tasks III and V) involves the possibility of converting the

enormous amount of nylon carpet waste, from the heavy concentration of carpet-manufacturing industry in the Dalton, Georgia area, into a pyrolysis char that would be suitable for tertiary treatment of waste water from the industrial plants of the area (particularly for the removal of dye components). Other possible couplings and groupings also are being assessed for feasibility and acceptability. In addition, latent mineral resources in the Appalachian region of Georgia are being considered as possible bases for new industrial groupings in the region.

Task IX. Initiation of Utilization Plan --

The program, agenda, list of invitees, graphics and other presentations material are being planned and developed for the first conference and workshop to be conducted on this program. This meeting is scheduled for sometime in January 1976, and will probably be held on the Georgia Tech campus. The principal objective of the first meeting of interested participants is to introduce the concept of synergistic co-siting to a broadly representative group of potential users of the results of this study, in the interest of stimulating the application and implementation of these results. In addition, it is desired that useful and beneficial feedback (suggestions and recommendations through the mechanism of the associated workshop session) will be obtained from the meeting participants into this project to guide the alignment and orientation of the investigative effort. Project team members are working closely with Mr. Michael Potterf, of the Appalachian Regional Commission, in the planning and development of the meeting program and list of invitees; and the emphasis of these efforts is on the structuring of an effective method of communicating the co-siting information to those who should find this information most useful.

IV. Plans for Next Reporting Period

During the next quarterly reporting period on this project (November 1, 1975 through January 31, 1976) the following efforts are planned:

- Completion of data-base development effort on Task I, with the exception of a small residual data-updating activity for a longer period of the project.

- Completion of preliminary search for co-siting candidates on Task II.

- Completion of preliminary chemical engineering analysis on Task III for selected co-siting candidates, based upon the input/output matrix format and analysis methodology developed to date.

- Continuation of development of scaling relationships for plant economics on Task IV, and incorporation of these relationships into overall economic-evaluation model.

- Continuation of selection of technically feasible co-siting groupings on Task V; completion of methodology development; evaluation of candidates selected on Tasks II and III.

- Initiation of Task VI, economic evaluation of technically feasible co-siting groupings on Task V; completion of methodology development; evaluation of candidates selected on Tasks II and III.

- Initiation of Task VI, economic evaluation of technically feasible groupings; development of evaluation model and methodology; use of these tools to evaluate candidates successfully screened on Task V.

- Continuation of regional application analysis, on Task VII, for North Georgia APDC region; select and evaluate promising prototype co-siting groupings that are appropriate for this region.

- Continued implementation of utilization plan; complete planning, development and arrangements for first seminar and workshop conference on the project; conduct this conference at Georgia Tech in January.

No significant problems have been encountered to date on this project, and originally anticipated progress and results are being achieved. No problems are anticipated for the next quarter of activity on the project.

Yours very truly,

Jack M. Spurlock, Ph.D.
Project Director

JMS/mam

cc: Mr. James T. McIntyre

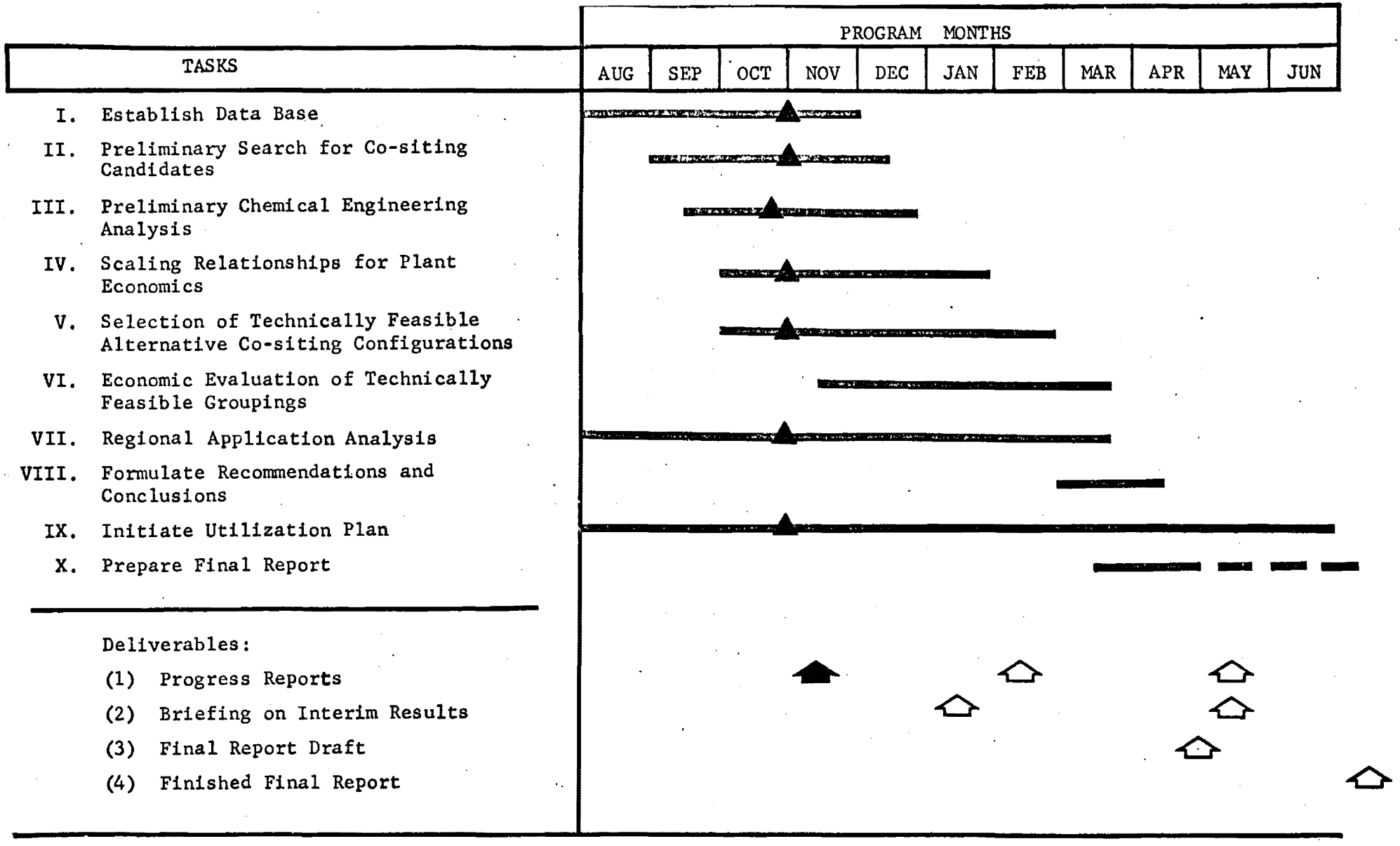


Figure 1. Program Schedule Plan and Current Task Status.

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 10, 1976

Appalachian Regional Commission
1666 Connecticut Avenue, N.W.
Washington, D.C. 20235

Attention: Mr. Michael A. Potterf
Room 627

Reference: ARC Grant No. GA-4234-75-I-302-0509
(Georgia Tech Project No. A-1772)

Subject: Quarterly Progress Report No. 2
"Study to Investigate Potential Benefits from Synergistic Co-siting of Industrial Activities"

Gentlemen:

This report summarizes progress on the referenced grant project for the period November 1, 1975 through January 31, 1976.

I. Introduction

The purpose of this program is to elucidate and evaluate the potential role of synergistic co-siting (i.e., mutually beneficial location and coupling of the input and output streams) of industrial plants, and other related activities, in the forming of policies and options for energy conservation, improvement of the environment, effective land use, and economic development of appropriate regions of the State of Georgia (primary emphasis) and the Appalachian Region. Anticipated results of this study include guidelines and recommendations for the practical application of co-siting in these regions, and the effective communication of the information to prospective

users who are likely to be involved in planning and implementing the appropriate applicational activities.

The specific objectives of the program are:

(1) the identification and classification of technical factors that have the greatest influence on the selection of co-siting groupings;

(2) the screening and selection of co-siting grouping possibilities that offer significant promise for providing important resource-utilization benefits (in Georgia's Appalachian areas specifically, as well as in the Appalachian Region generally);

(3) the economic evaluation of the selected co-siting grouping examples to establish cost-benefit comparisons between conventional and co-siting methods of industrial operations;

(4) the formulation, documentation and communication of recommendations and guidelines for --

- specific co-siting groupings that show very promising prospects as experimental prototypes, for selected regions of application, to demonstrate the benefits of synergistic co-siting methodology;
- use of the methodology developed on this program as an important new tool for industrial development activities in other locations of the Appalachian Region, etc.;
- further technology developments, policy analysis, etc., that will be required to broaden the potential scope of application of synergistic co-siting and provide the necessary incentives and stimulation for implementational initiatives by prospective users.

To meet these objectives, the following tasks constitute the overall work plan for the program:

Task I -- Data-base Development;

Task II -- Preliminary Search for Co-siting Candidates;

Task III -- Preliminary Chemical Engineering (Feasibility) Analysis for Candidates;

Task IV -- Development of Economic Model and Scaling Relationships;

Task V -- Selection of Technically Feasible Co-siting Groupings;

Task VI -- Economic Evaluation of Technically Feasible Groupings;

Task VII -- Regional Application Analysis;

Task VIII -- Formulate Recommendations and Conclusions;

Task IX -- Initiate Utilization Plan;

Task X -- Prepare and Distribute Final Report.

II. Project Schedule and Budget Status

The project effort is currently on schedule and operating within the budget plan. The revised schedule plan (as discussed in Quarterly Progress Report No. 1) is shown in Figure 1. On this figure, progress status is represented by the placement of a solid triangle on the time-line for each task that has been started thus far on the program. The location of the triangle represents the approximate degree of completion of that task (e.g., a triangle at about the mid-point of the task time-line indicates that the task effort is about 50 percent completed; a triangle at the end of the line denotes completion of the effort on that task). Milestones for project deliverables (reports, etc.) are represented by arrowheads; open arrowheads denote milestones that have not yet been accomplished, and solid symbols denote completed milestones.

Budget status is as follows:

(1)	Total Expenditures to Date:	$30,213
(2)	Expenditures by Categories:	
	(a) Direct Personal Services --	$16,959
	(b) Materials and Supplies --	$ 519
	(c) Travel --	$ 284
	(d) Computer Services --	-0-
	(e) Overhead and Benefits --	$12,451
(3)	Total Grant Funds Remaining:	$44,778

III. Technical Progress to Date

Technical progress during the second quarterly reporting period of the project is summarized below, by tasks, for those task items that were

scheduled for activity according to the schedule plan shown in Figure 1.

Overall Progress Summary

Effort was practically completed on Tasks I, II, III and IV; continued on Tasks V, VII, and IX; and initiated on Task VI (all described in Section I of this report). Project team personnel met with ARC, TVA, and Tennessee State representatives in Knoxville, Tennessee on December 2, 1975, and a briefing conference and workshop was held at Georgia Tech on January 20 for invited participants. Mr. Lewis L. Spruill, Director of the Georgia State Energy Office, was the keynote speaker at the conference and workshop and a total of thirty persons were in attendance.

Task I. Data-base Development --

A broad spectrum of pertinent data has been collected and compiled, including primary and secondary literature items on industrial plant siting technology; recent marketing and economic data and indicators for important industrial products; flowsheets, material and energy balances, and production technology for important industrial chemical processes; etc. This information has been screened and developed into a reference bibliography for the project. This data-base serves as the information foundation for the entire project. The work on this task is practically completed, but pertinent data and information will be added throughout the program as they become needed and available.

Task II. Preliminary Search for Co-siting Candidates --

A large number and wide variety of industrial processes and activities have been screened, based upon the data provided by Task I. Screening criteria were developed and used to evaluate the technical- and economic-viability potential for these processes in a co-siting mode of operation. The criteria are based principally on the relative potential benefit that each process could

provide or receive in a co-siting grouping, its economic growth potential over a reasonable and predictable period of time, and its potential versatility of application in a number of different co-siting grouping options. Examples of some of the industrial processes and activities that have been selected, thus far, for further evaluation include: waste processing (pyrolysis); stack-gas effluent-removal processes; waste-water treatment processes; fertilizer chemical processes; processes which use large quantities of coal (e.g., fossil-fuel power plants, energy-intensive industrial processes, coal-conversion processes, etc.); and several of the more economically important primary and intermediate inorganic and organic chemical manufacturing processes (e.g., sulfuric acid, chlorine, ethylene, methane, ethyl and methyl alcohol, etc.). This effort is practically completed.

Task III. Preliminary Chemical Engineering Analysis for Candidates --

This task effort was strongly coupled to the efforts on Tasks I and II The candidate individual processes selected on Task II for further evaluation were assessed for co-siting grouping roles. Initially, sets of paired processes and/or activities were studied for feasibility and potential synergism. Subsequently, groupings consisting of larger numbers of component processes/activities were identified and evaluated. The analysis consisted principally of developing input/output (raw materials and products, energy requirements and excesses, and by-products and wastes) matrices for several of the candidate processes and activities selected on Task II, using flowsheet, material balance and energy balance information obtained on Task I. From this matrix display of process input and output data, processes are identified which have a significant degree of matching potential among their input and output streams, and fundamental technical compatibility that would facilitate

the possible coupling of some of these streams. This effort is approximately completed.

Task IV. Scaling Relationships for Plant Economics --

Effort on this task was largely completed. Results of Task IV provide a basis for determining the effects of plant size and capacity on the economic characteristics of selected candidate groupings. These results support the economic evaluation effort on Task VI. Several sources of information relating to scaling criteria and techniques obtained on Task I were examined for validity, consistency and agreement. A large number of important processes of interest on this program are covered by the information compiled. The computer analysis procedure was adapted in part from existing plant-costing programs currently used at Georgia Tech.

Task V. Selection of Technically Feasible Co-siting Groupings --

Effort on this task is continuing. Inputs to this effort include the results derived from Tasks I, II, and III, described above. In particular, process-grouping candidates identified on Task III as having especially strong potential for matching of their input and/or output streams (to provide some important synergistic benefits), as well as apparent technical compatibility, are being studied in detail regarding several key factors. These factors include: (1) capacity compatibility (i.e., the raw-material or energy requirements of one process, in the capacity range necessary to justify its operations, can be met by the by-product or waste outputs of another process operating in its optimum range of capacity); (2) technological developments or design changes required to achieve effective and efficient coupling; and (3) other operational interfacing requirements and potential problems of coupling. Once these factors have been studied, those candidate groupings which still offer significant promise are characterized in a co-siting configu-

ration by detailed flowsheets, material balances and energy balances to the extent that reliable data are available from Task I. These configurations are carefully analyzed again for design and operational feasibility and the auspicious ones are then ready for in-depth economic-viability analysis on Task VI. The methodology for this procedure has been partially developed and is being applied (and refined as necessary) to candidate groupings available from the Task III effort.

Task VII. Regional Application Analysis --

The project team has met with representatives of the ARC, TVA and state of Tennessee (in Knoxville, Tennessee). From this activity important information has been obtained concerning specific problems associated with (1) the operations of present industry in that Appalachian region, and (2) the attracting of new, compatible industry into the region. This information is being assessed to provide the basis for the selection of specific examples of co-siting applications that would contribute to the solution of the problems and provide benefits through synergistic coupling of industrial activities (existing activities as well as promising new activities).

Task IX. Initiation of Utilization Plan --

The program, agenda, list of invitees, graphics and other presentations material were planned and developed for the first conference and workshop conducted on this program. This meeting was held at Georgia Tech on January 20, 1976. The principal objective of this first meeting of interested participants was to introduce the concept of synergistic co-siting to a broadly representative group of potential users of the results of this study, in the interest of stimulating the application and implementation of these results. In addition, useful and benficial feedback was obtained from the meeting participants. This is being used to guide the alignment and orientation of the investigative

effort. Project team members worked closely with Mr. Michael Potterf, of the Appalachian Regional Commission, and Mr. Phil Whitlow, of the State of Georgia's Office of Planning and Budget, in the planning and development of the meeting program and list of invitees. A complete list of the Attendees is shown in Attachment 1.

IV. Plans for Next Reporting Period

During the next quarterly reporting period on this project (February 1 through April 30, 1976) the following efforts are planned:

- Completion of selection of technically feasible co-siting groupings on Task V; completion of methodology development; evaluation of candidates selected on Tasks II and III.
- Completion of Task VI, economic evaluation of technically feasible co-siting groupings on Task V; completion of methodology development; evaluation of candidates selected on Tasks II and III.
- Completion of regional application analysis, on Task VII, for North Georgia APDC region; evaluation of promising prototype co-siting groupings that are appropriate for this region.
- Continued implementation of utilization plan; initiate planning, development and arrangements for second seminar and workshop conference on the project.
- Initiation of Task VIII, formulation of recommendations and conclusions.
- Initiation of Task X, final report preparation.

No significant problems have been encountered to date on this project, and originally anticipated progress and results are being achieved. No problems are anticipated for the next quarter of activity on the project.

Yours very truly,

Jack M. Spurlock, Ph.D.
Project Director

JMS/mam

cc: Mr. James T. McIntyre

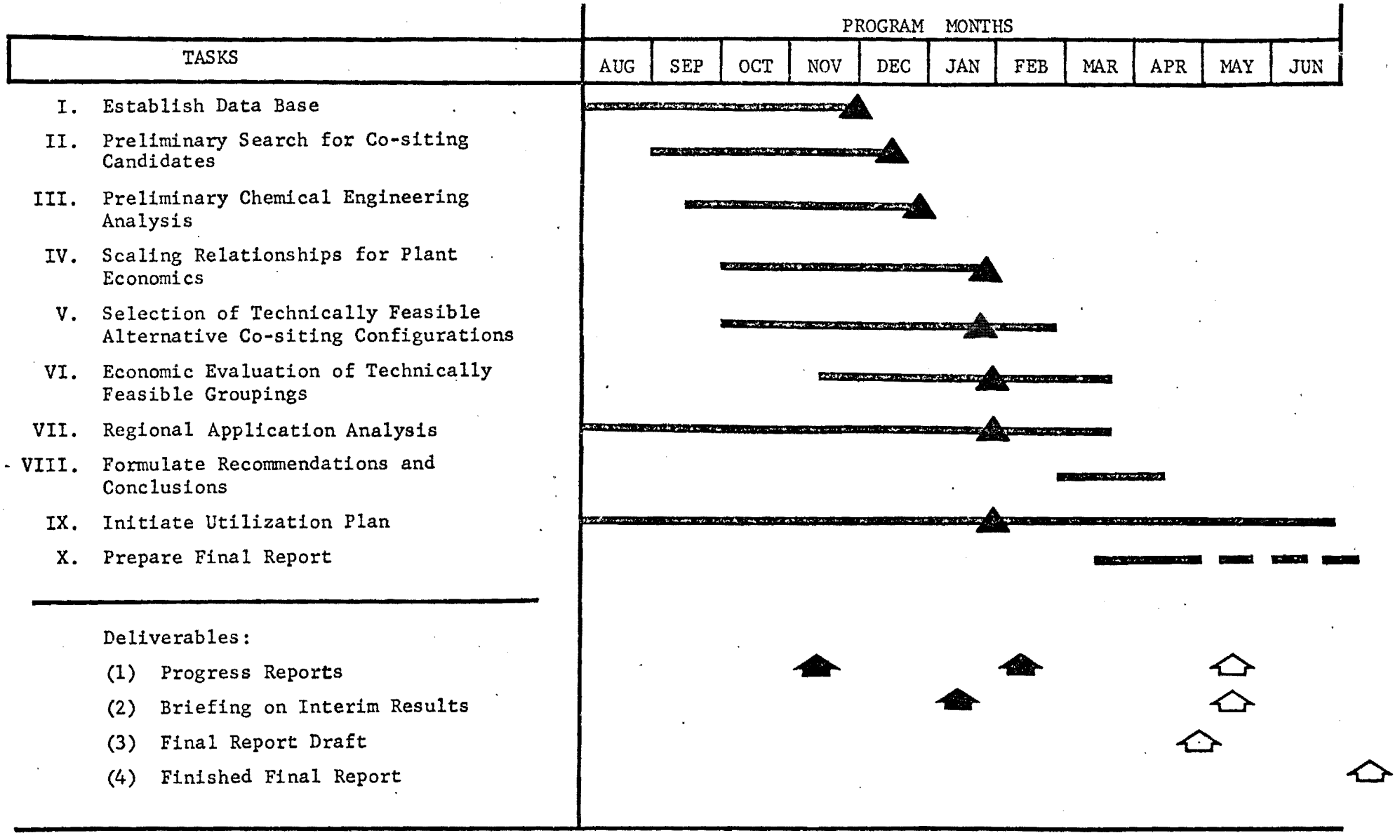


Figure 1. Program Schedule Plan and Current Task Status.

Attachment 1

First Co-siting Conference and Workshop - Held at Georgia Tech on January 20, 1976

List of Attendees

Name	Organization	Address & Phone #
William E. Davis	Dept. Ec. & Comm. Dev., State of Tennessee, Nasheville, Tenn.	(615)741-1087
Phil Whitlow	Ga. Office of Plann. & Budget	(404)656-3859
Michael A. Potterf	A.R.C.	(202)967-3671
Darrell Gilliam	Ky. Dev. Cabinet - ARC Program	(502)564-7670
Anita M. Fey	EES, Georgia Tech	(404)894-3450
Willard R. Fey	ISYE, Georgia Tech	(404)894-2359
Lewis L. Spruill	Ga. State Energy Office	(404)656-5176
Jeffrey S. Tiller	EES, Georgia Tech	(404)894-3450
Don Nicholson	GMAPDC	(404)536-3431
Larry Glasco	GMAPDC	(404)536-3431
Dick Cowles	FEA	(202)254-9755
E. P. Lomasney	EPA, Southeast Region	(404)526-5201
Ken Kessler	No. Ga. APDC	(404)226-1672
Gunter Newsom	Atlanta Regional Commission	(404)522-7577
Hal Maggied	Georgia Dept. of Transportation	(404)363-7583
Warren Zurn	FEA	(404)526-5463
Hearn Lumpkin	Ga. Power Company	(404)522-6060
Ralph D. Carnathan	TVA, Knoxville, Tenn.	(615)637-0101
Jim Corrigan	NE GA PDC, Athens	(404)548-3141
Bob Hammond	NE GA PDC	(404)548-3141
Charlie Minors	Georgia Power Co.	(404)522-6060
John R. Gilliland	Bureau of Industry and Trade	(404)656-3580
Walter G. Belter	Energy Research and Dev. Admin.	(301)973-4556
Lee R. Hasty	Chattahoochee-Flint APDC Admin.	(404)882-2956
Robert M. Mason	Georgia Tech, EES	(404)894-3450
Gordon R. Harrison	Georgia Tech, EES	(404)894-3430

First Co-siting Conference and Workshop - Held at Georgia Tech on January 20, 1976

List of Attendees

Name	Organization	Address & Phone #
John E. Husted	Georgia Tech, Ch.E. and EES	(404)894-3630
Dalip Sondhi	Georgia Tech, EES	(404)894-3414
Henderson C. Ward	Georgia Tech, Ch.E. and EES	(404)894-3414
Jack M. Spurlock	Georgia Tech, EES	(404)894-3414

A-1772

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

May 10, 1976

Appalachian Regional Commission
1666 Connecticut Avenue, N.W.
Washington, D.C. 20235

Attention: Mr. Michael A. Potterf
Room 627

Reference: ARC Grant No. GA-4234-75-I-302-0509
(Georgia Tech Project No. A-1772)

Subject: Quarterly Progress Report No. 3
"Study to Investigate Potential Benefits from Synergistic Co-siting of Industrial Activities"

Gentlemen:

This report summarizes progress on the referenced grant project for the period February 1 through April 30, 1976.

I. Introduction

The purpose of this program is to elucidate and evaluate the potential role of synergistic co-siting (i.e., mutually beneficial location and coupling of the input and output streams) of industrial plants, and other related activities, in the forming of policies and options for energy conservation, improvement of the environment, effective land use, and economic development of appropriate regions of the State of Georgia (primary emphasis) and the Appalachian Region. Anticipated results of this study include guidelines and recommendations for the practical application of co-siting in these regions, and the effective communication of the information to prospective users who are likely to be involved in planning and implementing the appropriate applicational activities.

The specific objectives of the program are:

(1) the identification and classification of technical factors that have the greatest influence on the selection of co-siting groupings;

(2) the screening and selection of co-siting grouping possibilities that offer significant promise for providing important resource-utilization benefits (in Georgia's Appalachian areas specifically, as well as in the Appalachian Region generally);

(3) the economic evaluation of the selected co-siting grouping examples to establish cost-benefit comparisons between conventional and co-siting methods of industrial operations;

(4) the formulation, documentation and communication of recommendations and guidelines for --

- specific co-siting groupings that show very promising prospects as experimental prototypes, for selected regions of application, to demonstrate the benefits of synergistic co-siting methodology;
- use of the methodology developed on this program as an important new tool for industrial development activities in other locations of the Appalachian Region, etc.;
- further technology developments, policy analysis, etc., that will be required to broaden the potential scope of application of synergistic co-siting and provide the necessary incentives and stimulation for implementational initiatives by prospective users.

To meet these objectives, the following tasks constitute the overall work plan for the program:

Task I -- Data-base Development;

Task II -- Preliminary Search for Co-siting Candidates;

Task III -- Preliminary Chemical Engineering (Feasibility) Analysis for Candidates;

Task IV -- Development of Economic Model and Scaling Relationships;

Task V -- Selection of Technically Feasible Co-siting Groupings;

Task VI -- Economic Evaluation of Technically Feasible Groupings;

Task VII -- Regional Application Analysis;

Task VIII -- Formulate Recommendations and Conclusions;

Task IX -- Initiate Utilization Plan;

Task X -- Prepare and Distribute Final Report.

II. Project Schedule and Budget Status

The project effort is currently on schedule and operating within the budget plan. The revised schedule plan, as coordinated with and approved by Mr. Michael A. Potterf of the Appalachian Regional Commission, is shown in Figure 1. (A no-cost extension of the contract performance period has been requested based on this revised schedule.) On this figure, progress status is represented by the placement of a solid triangle on the time-line for each task that has been started thus far on the program. The location of the triangle represents the approximate degree of completion of that task (e.g., a triangle at about the mid-point of the task time-line indicates that the task effort is about 50 percent completed; a triangle at the end of the line denotes completion of the effort on that task). Milestones for project deliverables (reports, etc.) are represented by arrowheads; open arrowheads denote milestones that have not yet been accomplished, and solid symbols denote completed milestones.

Budget status is as follows:

(1)	Total Expenditures to Date:	$47,940
(2)	Expenditures by Categories:	
	(a) Direct Personal Services --	$26,780
	(b) Materials and Supplies --	$ 682
	(c) Travel --	$ 623
	(d) Computer Services --	$ 87
	(e) Overhead and Benefits --	$19,768
(3)	Total Grant Funds Remaining:	$27,051

III. Technical Progress to Date

Technical progress during the third quarterly reporting period of the project is summarized below, by tasks, for those task items that were scheduled for activity according to the schedule plan shown in Figure 1.

Overall Progress Summary

Tasks I through VII were extended to encompass a range of industrial plants, products, and waste products as well as to specifically include the energy requirements associated with each. Project team personnel met with Mr. Michael A. Potterf of the Appalachian Regional Commission in Washington, D.C. on March 16 to discuss this extension. Also at this meeting, plans were discussed relating to Task IX (the Utilization Plan) to include in this task the development of a user-interactive computer program to augment the application of the results of this study in the ARC. Efforts have been initiated on the development of this program.

Task I. Data-base Development --

A broad spectrum of pertinent data has been collected and compiled, including primary and secondary literature items on industrial plant siting technology; recent marketing and economic data and indicators for important industrial products; flowsheets, material and energy balances, and production technology for important industrial chemical processes,etc. This information has been screened and developed into a reference bibliography for the project. The data base has been extended during this reporting period to include more industrial plants, products, and waste products as well as to specifically break out the energy requirements associated with each. This data-base serves as the information foundation for the entire project. The work on this task is now practically completed, but pertinent data and information will be added throughout the program as they become needed and available.

Task II. Preliminary Search for Co-siting Candidates --

A large number and variety of industrial processes and activities have been screened, based upon the data provided by Task I. Screening criteria were developed and used to evaluate the technical- and economic-viability

potential for these processes in a co-siting mode of operation. The criteria are based principally on the relative potential benefit that each process could provide or receive in a co-siting grouping, its economic growth potential over a reasonable and predictable period of time, and its potential versatility of application in a number of different co-siting grouping options. Examples of some of the industrial processes and activities that have been selected, thus far, for further evaluation include: waste processing (pyrolysis); stack-gas effluent-removal processes; waste-water treatment processes; fertilizer chemical processes; processes which use large quantitites of coal (e.g., fossil-fuel power plants, energy-intensive industrial processes, coal-conversion processes, etc.); and several of the more economically important primary and intermediate inorganic and organic chemical manufacturing processes (e.g., sulfuric acid, chlorine, ethylene, methane, ethyl and methyl alcohol, etc.). This effort was continued based on the extension of Task I but is now practically completed.

Task III. Preliminary Chemical Engineering Analysis for Candidates --

This task effort was strongly coupled to the efforts on Tasks I and II. The candidate individual processes selected on Task II for further evaluation were assessed for co-siting grouping roles. Initially, sets of paired processes and/or activities were studied for feasibility and potential synergism. Subsequently, groupings consisting of larger numbers of component processes/activities were identified and evaluated. The analysis consisted principally of developing input/output (raw materials and products, energy requirements and excesses, and by-products and wastes) matrices for several of the candidate processes and activities selected on Task II, using flowsheets, material balance and energy balance information obtained on Task I. From this matrix display of process input and output data, processes are identified which have a significant degree of matching potential among their input and output streams, and

fundamental technical compatibility that would facilitate the possible coupling of some of these streams. This effort was expanded to include the enlargement of the data base and to include the development of a computer technique for providing the connection orders (up to five) between the various plants. This effort is now approximately completed.

Task IV. Scaling Relationships for Plant Economics --

Effort on this task is continuing. Results of Task IV provide a basis for determining the effects of plant size and capacity on the economic characteristics of selected candidate groupings. These results support the economic evaluation effort on Task VI. Several sources of information relating to scaling criteria and techniques obtained on Task I were examined for validity, consistency and agreement. A large number of important processes of interest on this program are covered by the information compiled. The computer analysis procedure was adapted in part from existing plant-costing programs currently used at Georgia Tech.

Task V. Selection of Technically Feasible Co-siting Groupings --

Effort on this task is continuing. Inputs to this effort include the results derived from Tasks I, II, and III, described above. In particular, process-grouping candidates identified on Task III as having especially strong potential for matching of their input and/or output streams (to provide some important synergistic benefits), as well as apparent technical compatibility, are being studied in detail regarding several key factors. These factors include: (1) capacity compatibility (i.e., the raw-material or energy requirements of one process, in the capacity range necessary to justify its operations, can be met by the by-product or waste outputs of another process operating in its optimum range of capacity); (2) technological developments or design changes required to achieve effective and efficient coupling; and (3) other operational

interfacing requirements and potential problems of coupling. Once these factors have been studied, those candidate groupings which still offer significant promise are characterized in a co-siting configuration by detailed flowsheets, material balances and energy balances to the extent that reliable data are available from Task I. These configurations are carefully analyzed again for design and operational feasibility and the auspicious ones are then ready for in-depth economic-viability analysis on Task VI. The methodology for this procedure has been developed and is being applied (and refined as necessary) to candidate groupings available from the Task III effort.

Task VII. Regional Application Analysis --

The feedback from the participants in the conference and workshop held at Georgia Tech on January 20 has been carefully reviewed and analyzed. This review and analysis has been used to guide the alignment of the investigative effort particularly in the selection of examples of co-siting applications that would contribute to the solution of the problems identified by the participants. Synergistic coupling of both existing as well as promising new activities are being considered to show the benefits that could be attained. Information has been requested from the North Georgia APDC pertaining to the requirements of tertiary waste-water treatment of carpet-industry dye waste. This information will be used in the North Georgia Co-siting example currently under investigation.

Task IX. Initiation of Utilization Plan --

The effort on this task has been principally concerned with the development of a user-interactive computer program for the selection of co-sited groupings that match the requirements of a community or region. The program is in the user-conversational mode and does not require the user to have detailed knowledge of the internal computer program. Its main purpose is to

permit industrial planners to match the characteristics and needs of their areas with co-siting possibilities that would be technically and economically feasible in meeting their requirements.

IV. Plans for Next Reporting Period

During the next quarterly reporting period on this project (April through June 30, 1976) the following efforts are planned:

- Completion of selection of technically feasible co-siting groupings on Task V; evaluation of candidates selected on Tasks II and III.
- Completion of Task VI, economic evaluation of technically feasible co-siting groupings on Task V; evaluation of candidates selected on Tasks II and III.
- Completion of regional application analysis, on Task VII, for North Georgia APDC region; evaluation of promising prototype co-siting groupings that are appropriate for this region.
- Continued implementation of utilization plan; initiate planning, development and arrangements for second seminar and workshop conference on the project.
- Initiation of Task VIII, formulation of recommendations and conclusions.

No significant problems have been encountered to date on this project, and originally anticipated progress and results are being achieved. No problems are anticipated for the next quarter of activity on the project.

Yours very truly,

Jack M. Spurlock, Ph.D.
Project Director

JMS/mam
cc: Mr. James T. McIntyre

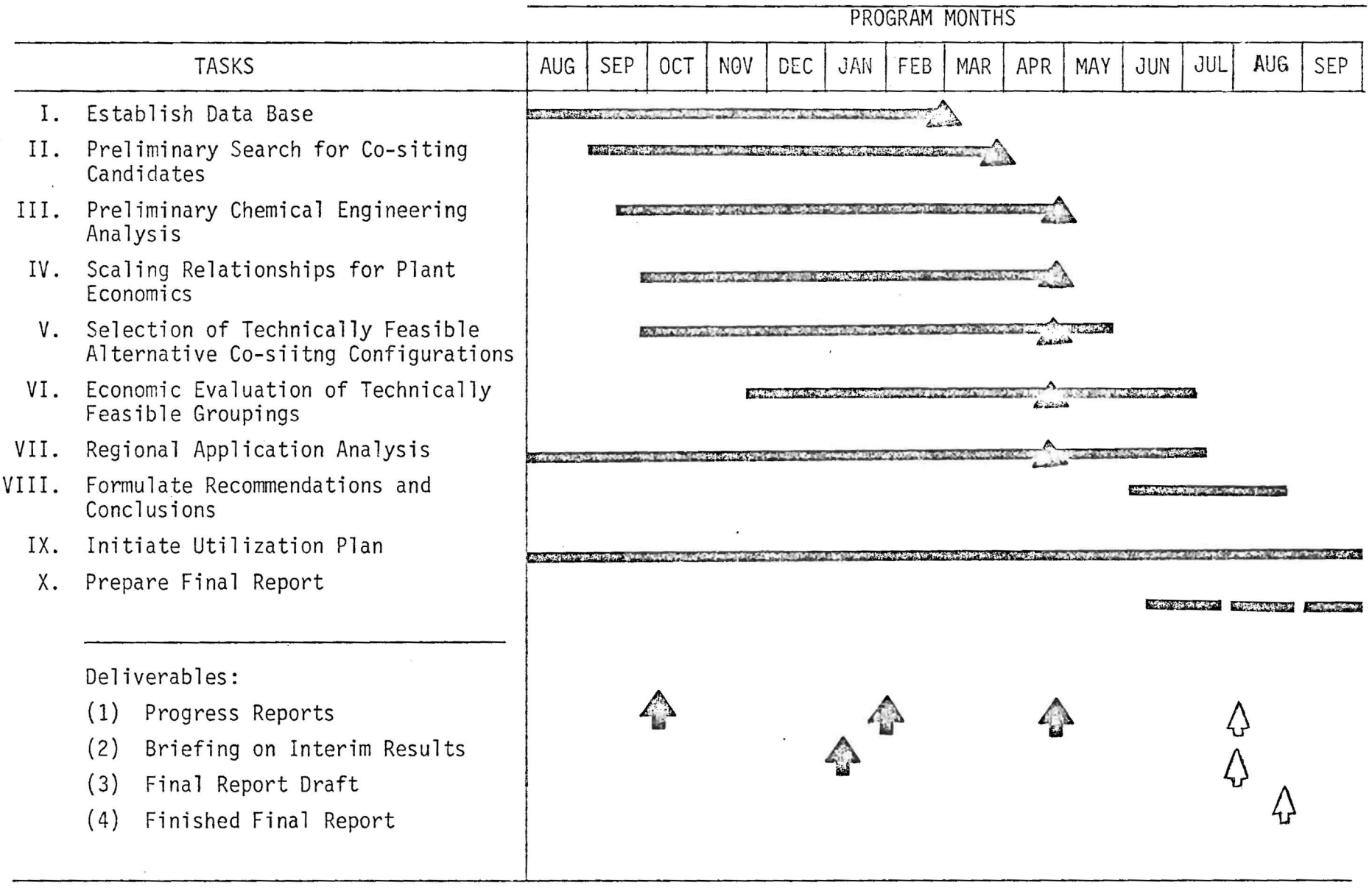


Figure 1. Program Schedule Plan and Current Task Status. (Revised based on anticipated no-cost extension.)

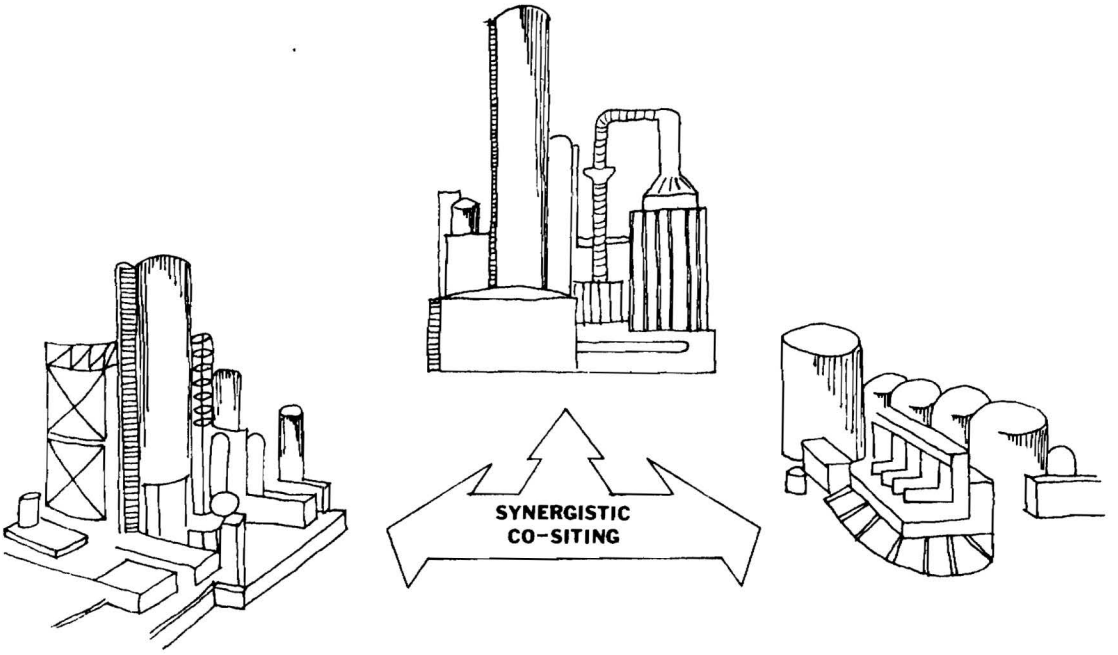
A-1772

USER MANUAL

GUIDELINES FOR SYNERGISTIC CO–SITING

By

J. M. Spurlock and H. C. Ward, Principal Investigators
J. T. Sommerfeld and D. K. Sondhi



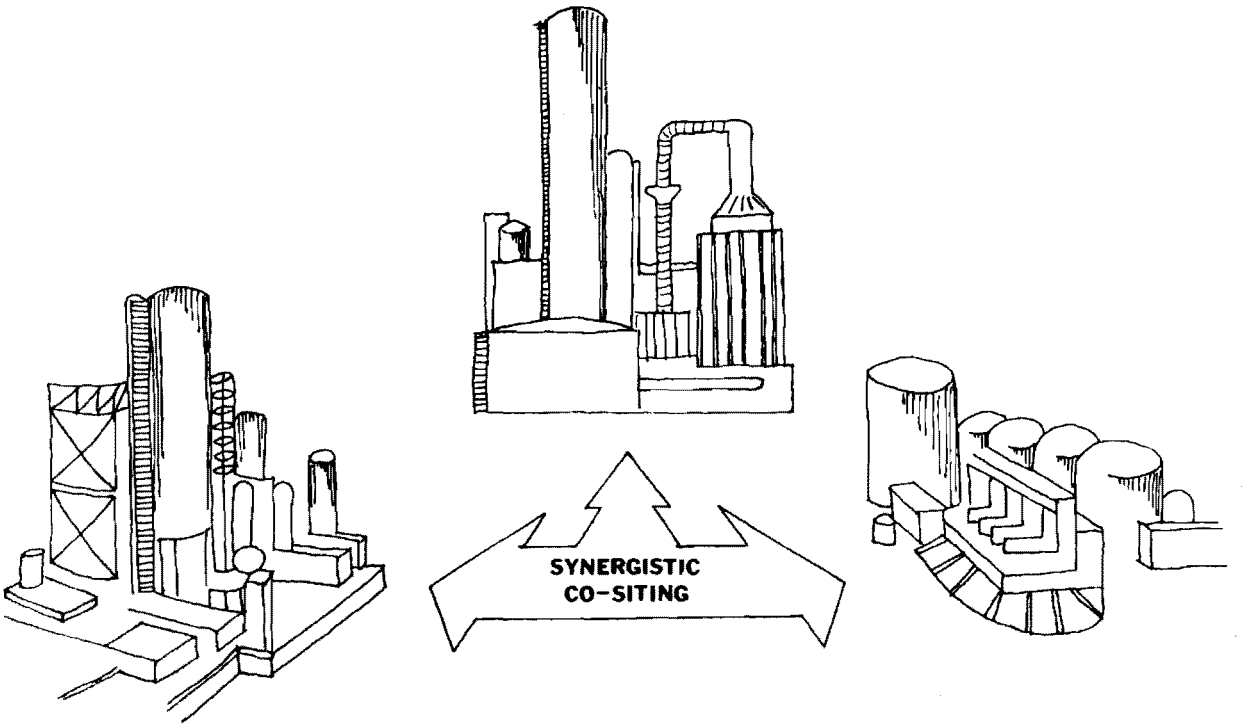
September 1976

1976

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

Appalachian Regional Commission Grant Number GA–4234–75–I–302–0509
Georgia Tech Project A-1772

GUIDELINES FOR SYNERGISTIC CO-SITING



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1.0 PREFACE

During the period August, 1975, - September, 1976, a program was conducted by the Engineering Station of the Georgia Institute of Technology for the Appalachian Regional Commission to elucidate and evaluate the potential role of synergistic co-siting for the planning of industrial development of appropriate regions of the State of Georgia (primary emphasis) and the Appalachian Region.

This manual was prepared as a supplement to the final report for this study. Its purpose is to summarize the essential features and applications of synergistic co-siting methodology, including the user-interactive computer program, that was developed on this study. For technical details, the reader is referred to the final report which is available from either the Appalachian Regional Commission or the Georgia Institute of Technology. Appropriate addresses for requesting this report are:

Appalachian Regional Commission
1666 Connecticut Avenue, N.W.
Washington, D. C. 20235
Attn: Mr. Michael Potterf

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332
Attn: Dr. Jack M. Spurlock

2.0 INTRODUCTION

In this section, the major features and applications of synergistic co-siting are explained.

■ What is synergistic co-siting?

Synergistic co-siting is the carefully planned grouping of industrial and/or agricultural activities in complexes that provide mutually beneficial utilization of energy, raw materials, co-products, land, plant wastes, and transportation facilities, as well as promote greater economical attractiveness of pollution-control measures, resource recovery, etc.

■ What is the significance of synergistic co-siting?

Synergistic co-siting approaches to industrial-site planning, and to plant and process design, offer the promise of some very effective and exciting possibilities for the simultaneous achievement of certain critical national goals such as resources (including energy) conservation, new energy sources, effective land use, improved food supply, improved environmental quality, and beneficial industrial development.

■ What are some possible benefits of synergistic co-siting?

- *ENERGY CONSERVATION*
- *DEVELOPMENT OF NEW SOURCES OF FEEDSTOCKS*
- *ECONOMICAL RESOURCE AND WASTE RECOVERY*
- *IMPROVED METHODS OF (AND INCENTIVE FOR) POLLUTION CONTROL*
- *IMPROVED LAND USE*
- *OPTIMIZATION OF TRANSPORTATION USE*
- *ELECTRICAL-POWER COST ADVANTAGES*
- *IMPROVED STABILITY OF LABOR POOLS AND JOB OPPORTUNITIES*
- *INCREASED INCENTIVE FOR CAR-POOLING*

- IMPROVED BASIS FOR USE OF HIGH-TEMPERATURE GAS-COOLED NUCLEAR REACTORS
- IMPROVED BASIS FOR COMMUNITY PLANNING
- REDUCTION IN SITE-APPROVAL TIME FOR NEW PLANTS
- IMPROVED BASIS FOR ATTRACTING NEW INDUSTRY AND INCREASED PLANT-SITINGS
- MORE ECONOMICAL BASIS FOR PLANT SERVICES
- AGRICULTURAL BENEFITS
- IMPROVED PRODUCT MIX
- LOWER UNIT PRODUCT COST
- REDUCTION OF OFF-SITE FACILITIES COST

■ In what functions can synergistic co-siting be effectively used?

- *policy planning at the federal, regional, state, and local levels*
- *industrial development planning and analysis*
- *industrial site selection and plant design*

■ What are the general co-siting modes?

- *coupling of existing plants within a limited geographical area*
- *coupling of existing or presently proposed plants with new plants*
- *development of entirely new complexes*

■ What are typical criteria for synergistically coupling industrial and/or agricultural activities?

- PRODUCT OF ACTIVITY A → RAW MATERIAL OF ACTIVITY B
- WASTE PRODUCT (EFFLUENT) OF ACTIVITY A → RAW MATERIAL OF ACTIVITY B
- WASTE ENERGY OF ACTIVITY A → ENERGY REQUIREMENT OF ACTIVITY B
- WASTE FROM ACTIVITY A → WASTE-PROCESSING ACTIVITY → PRODUCT/ RAW MATERIALS
- INTERMEDIATE OR BY-PRODUCT FROM ACTIVITY A → RAW MATERIAL OF ACTIVITY B
- COMMON FUEL/FEEDSTOCK → INPUT TO ACTIVITY A; INPUT TO ACTIVITY B
- PRODUCT/BY-PRODUCT OF ACTIVITY A → ACTIVITY C → RAW MATERIAL OF ACTIVITY B
- WASTE/EFFLUENT FROM ACTIVITY A; WASTE/EFFLUENT FROM ACTIVITY B → COMMON WASTE-TREATMENT ACTIVITY

■ What are some possible tradeoff factors that could affect the selection of co-sited activites?

- *Carryover fire/explosion vulnerability ("domino effect")*
- *Larger storage pools of hazardous chemicals*
- *National defense vulnerability*
- *Reliability interdependency among industrial units*

- Effect on protection of proprietary processes
- Ownership/management structure
- Reliability of raw material and feedstock availability
- Regional and community impact (two-way)
- Availability of suitable land for all units
- Availability of fuels and energy for all units
- Availability of transportation networks
- Proximity to markets and raw materials for all units

■ What systematic steps comprise synergistic co-siting methodology developed to date?

- Preliminary search for co-siting candidates based on regional application analysis
- Selection of technically feasible co-siting groupings
- Economic evaluation of co-sited groupings

■ In what form is this synergistic co-siting methodology presently available for use?

A user-interactive computer program has been developed and is available for use on a service basis at Georgia Tech. This program is described and typical examples of its use are presented in Section 3.

3.0 USER-INTERACTIVE COMPUTER PROGRAM

3.1 General Description

This section describes the application of a user-interactive computer program that was developed to facilitate and encourage the use of synergistic co-siting methodology. It provides for the screening, selection, and economic comparison of co-sited industrial groupings. The program involves an interrogative-conversational format and consists of the following list of questions and guideline statements:

1. HAVE YOU USED THIS PROGRAM BEFORE?
2. DO YOU WANT A DESCRIPTION OF THIS PROGRAM?
3. DO YOU WANT A LIST OF THE 88 INDUSTRIES INCLUDED IN THE DATA BASE OF THIS PROGRAM?
4. DO YOU WANT A LIST OF SOURCES OF DESCRIPTIVE INFORMATION FOR INDUSTRIES IN THE DATA BASE?
5. WOULD YOU LIKE TO PERFORM A SEARCH FOR CO-SITING CANDIDATES FOR A SPECIFIC CORE OF INDUSTRIES?
6. HOW MANY INDUSTRIES CONSTITUTE THE CORE OF THE COMPLEX YOU ARE CONSIDERING? (THE CORE MAY CONSIST OF NEW INDUSTRIES ONLY, EXISTING INDUSTRIES ONLY, OR BOTH NEW AND EXISTING INDUSTRIES.)
7. LIST THE CODES OF THE INDUSTRIES IN THE CORE.
8. AT THIS POINT WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF INDUSTRIES AND BEGIN ANOTHER SEARCH FOR CO-SITING CANDIDATES FOR THIS CORE?
9. WOULD YOU LIKE TO PERFORM AN ECONOMIC ANALYSIS FOR A SPECIFIC COMPLEX?
10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU SPECIFY MERCHANT CAPACITIES?
11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE COMPLEX AND THEIR MERCHANT CAPACITIES, I.E., INDUSTRY NUMBER, CAPACITY (TONS/YEAR).

12. SEVERAL OPTIONS ARE AVAILABLE FOR THE ANNUAL INCREASE IN THE COST OF CHEMICAL PLANTS. INCORPORATED IN THIS COMPUTER PROGRAM, AS OPTION (1), FOR THIS RATE OF INCREASE IS THE AVERAGE MARSHALL-STEVENS INDEX FOR THE YEAR 1975, WITH AN ALLOWANCE FOR AN ANNUAL AVERAGE INCREASE OF 4.5 PERCENT FOR YEARS BEYOND 1975 IN WHICH A PLANT MIGHT BE CONSTRUCTED. OPTION (2) PROVIDES FOR THE SPECIFICATION OF ANY MARSHALL-STEVENS INDEX OF INTEREST. OPTION (3) IS A MODIFICATION OF OPTION (1) WHICH USES THE MARSHALL-STEVENS INDEX INCORPORATED IN THE PROGRAM FOR THE YEAR 1975, BUT PERMITS THE USER TO SPECIFY AN ANNUAL INCREASE OTHER THAN 4.5 PERCENT BEYOND THE 1975 INDEX VALUE.

    TYPE IN THE OPTION YOU PREFER.

13A. TYPE IN THE YEAR OF INTEREST (OPTION 1 ONLY).

13B. TYPE IN THE MARSHALL-STEVENS INDEX OF INTEREST (OPTION 2 ONLY).

13C. TYPE IN THE YEAR OF INTEREST (1975 OR LATER) AND THE ANNUAL PERCENT OF INCREASE (OPTION 3 ONLY), I.E., YEAR, ANNUAL PERCENT.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH A DIFFERENT ANNUAL INCREASE IN PLANT COSTS?

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR ANOTHER COMPLEX?

15B. DO YOU WANT TO USE THE SAME PLANT-COST BASIS IN THIS ANALYSIS YOU CHOSE IN RESPONSE TO STATEMENTS 12 AND 13 IN THE PREVIOUS ANALYSIS?

16. WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF INDUSTRIES AND BEGIN ANOTHER SEARCH FOR CO-SITING CANDIDATES FOR THIS CORE?

As can be seen from the above list, the format utilizes procedural and explanatory steps that are tailored for the experience level of the individual user. Responses selected by the user for each of the questions or guideline statements determine the sequence of further steps in the procedural format. This is demonstrated in the logic diagram for the overall program shown in Figure 3-1.

The overall functions performed for the user by the computer program are accomplished in three major groupings of the 16 statements. These groupings are explained below.

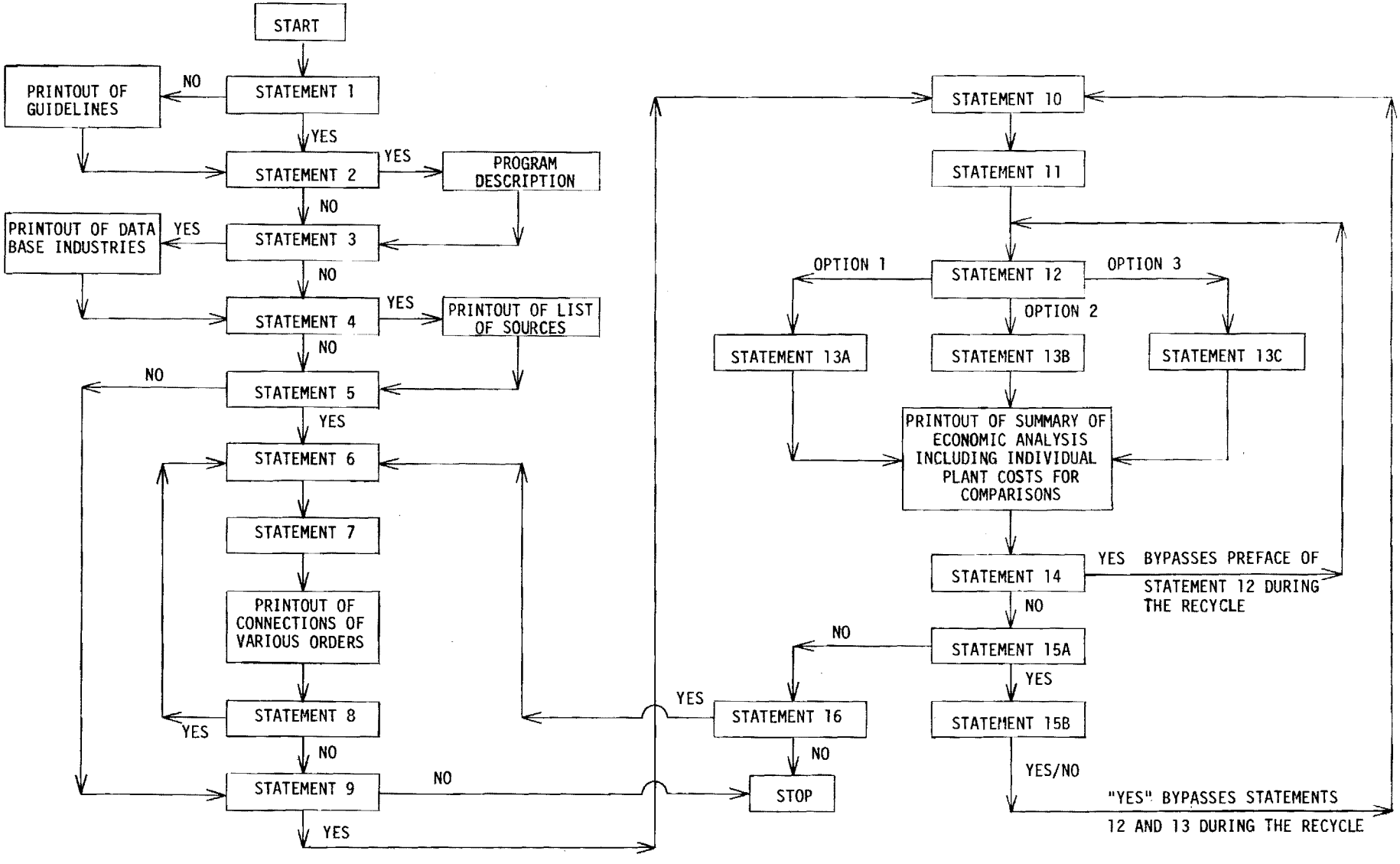


Figure 3-1. Logic Diagram of the User-Interactive Computer Program

GROUP 1 (Statements 1-4): This segment of the program provides the user with background information relating to steps in the program and items in the data base. It is necessary that a new user (i.e., unskilled in the use of the program) request the list of chemicals which are included in the data base of the program in order to obtain the code numbers of chemicals or industries which will be required as input information in response to later statements.

An option is also available for the user to request a list of references which may be consulted for general information on chemical processes.

GROUP 2 (Statements 5-8): This segment of the program searches for co-siting candidates and prints connections of various orders. The user is required to provide a "core" which may consist of one or more than one chemical commodity. For example, a local abundance of coal might suggest a coal-based complex and in this case coal alone would constitute the "core." In general, as far as the user is concerned, there are no restrictions regarding chemicals or their number that may comprise the "core," as long as they are listed in the data base.

The printout consists of items listed under the titles "COMPONENT 1" and "COMPONENT 2." The item(s) listed under "COMPONENT 1" are the chemicals which the user provides as the "core." The chemicals under "COMPONENT 2" are the appropriate potential co-siting candidates.

The term "order of connection" can be best explained through an example. Consider the simple production schemes in Figure 3-2 below including only one of the many processes involving coal.

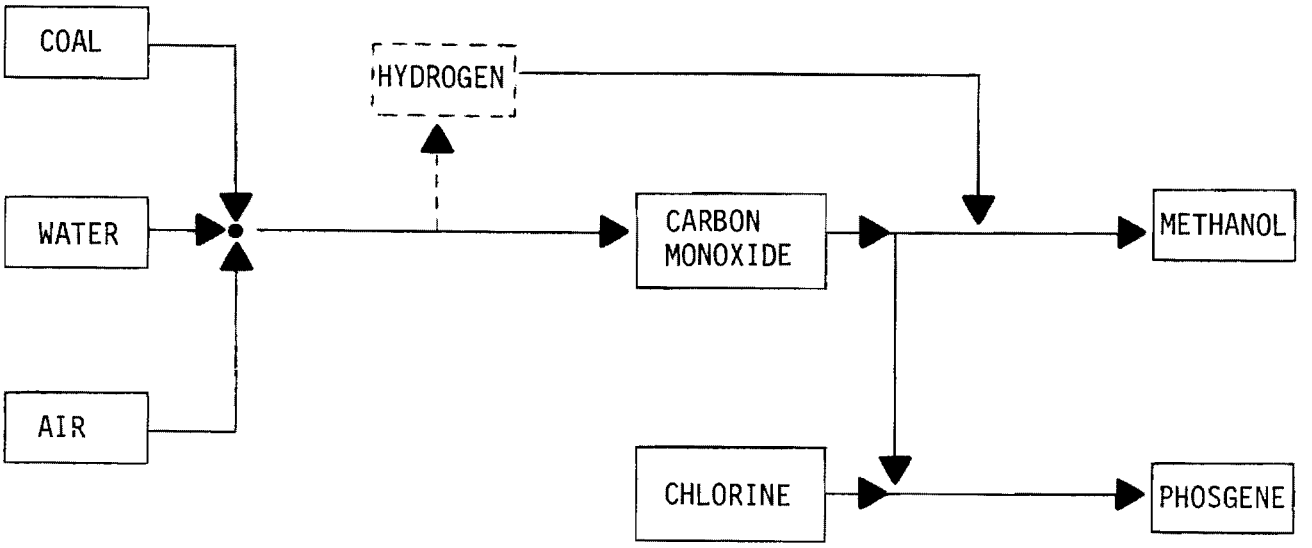


Figure 3-2. Schematic Example of Process Connections.

In the above example, the unique connections are (neglecting air and water as explained below):

first-order (direct coupling) between --

COAL	and	CARBON MONOXIDE
CARBON MONOXIDE	and	METHANOL, HYDROGEN, AND PHOSGENE
HYDROGEN	and	METHANOL
CHLORINE	and	PHOSGENE

second-order (coupling through one intermediate component) between --

COAL	and	METHANOL, HYDROGEN, AND PHOSGENE
CARBON MONOXIDE	and	CHLORINE, HYDROGEN, AND METHANOL
METHANOL	and	HYDROGEN AND PHOSGENE
PHOSGENE	and	HYDROGEN

third-order (coupling through two intermediate components) between --

COAL	and	CHLORINE, HYDROGEN, AND METHANOL
HYDROGEN	and	CHLORINE AND PHOSGENE
METHANOL	and	CHLORINE AND PHOSGENE

fourth-order (coupling through three intermediate components) between --

CHLORINE	and	HYDROGEN AND METHANOL

It would appear from the example schematic diagram (Figure 3-2) that coal and hydrogen should be related by a first-order connection. However, since carbon monoxide was designated to be the principal product of interest from the reaction of coal, air and water, hydrogen was designated as a by-product. In this respect, since the computer program permits only one first-order connection between a product and each of the input materials for a given process, the choice for this connection must be the one relating to the principal product; then the by-products are considered to be second-order connections with the materials that are inputs to the process. Therefore, in this example, coal and hydrogen are shown to be related first by a second-order connection. In turn, the principal product and the by-product(s) of a process are considered to be related by a first-order connection (i.e., the principal product causes the other(s) to be produced without any further chemical reaction steps). In addition, connections for air and water are not shown since both are considered to be cost-free materials and do not appear in the data base. Also, only the lowest connection order for two materials will be shown in the computer printout. For example, in the process-connection scheme shown in Figure 3-2, although carbon monoxide and hydrogen are connected both by first-order (principal product to by-product) and second-order (through methanol) relationships, only the first-order connection would be shown in the computer printout. Similarly, only the lowest-order connections for the other components would be printed out.

GROUP III (Statements 9-16): This segment deals with the economic analysis for a chosen complex. Following is an explanation of the terms and abbreviations which appear in the printout of the economic analysis:

CAPTIVE PRODUCTION - Production of a chemical which is consumed within the complex itself. A negative value indicates generation of a by-product.

MERCHANT PRODUCTION - Production which will be shipped to markets outside the complex (i.e., external).

TOTAL PRODUCTION - Sum of captive and merchant productions.

REMARKS - Displays the role of certain chemicals either as by-products or as raw materials for the convenience of the user. In the case of ethylene glycol, "NO DATA" will appear under this column; plant costs for this chemical are included in those for ethylene oxide from which it is derived.

PLANT COST - Costs shown are capital costs only. Not included are offsite facilities, land costs, and utilities.

PRODUCT VALUE - Product market values are computed and displayed for items which have a non-zero merchant production.

RAW MATERIAL COST - Market value of raw materials consumed in the complex.

BY-PRODUCT CREDIT - Credit value associated with the generation of by-products which are shipped outside the complex.

POWER - Power consumed for the total production of a chemical. Shown for only those items with which a plant cost is associated.

TPY - Tons/year.

MM$ - Millions of dollars

MM$PY - Millions of dollars per year.

MW - Megawatts.

The list of 88 "industries" in the data base, which the computer program will provide if so instructed in Statement 3, includes six basic raw materials identified by ** and twenty-one by-product materials identified by * (a print-out of these "industries" is shown in Section 3.2.2). Due to the roles of these

materials in the various processing schemes considered in the methodology, merchant capacities should not be specified for any of these materials in response to Statement 11. However, any of these materials may be considered as core industries in response to Statement 7.

It should also be noted that neither air nor water is listed in the data base since they were assumed to be available at no cost. However, they were included where required in the computational procedures and are shown on flow-sheets presented in this report.

3.2 Illustrative Example

3.2.1 Description and Discussion

The essential features and applicational significance of this user-interactive program can best be characterized by the following illustrative example. The example case involves the identification and economic comparison, for the year 1975 based on the Marshall-Stevens Index, of feasible co-siting groupings for the use of a locally available supply of coal. This will demonstrate the use of the interactive computer procedure in accomplishing an example regional applicational analysis.

The computer printout for this illustrative example is provided in Section 3.2.2 and has the statement format described earlier in Section 3.1. Guidelines for and responses to the various computer statements are as follows:

- Statements 1-5. The first 5 statements of the format are straightforward and prepare the user, based on his background, for the computer procedure. For illustrative purposes, the responses were: -- "no," "yes," "yes," "yes," and "yes," respectively.
- Statement 6. Since in this example, only one industry (coal) constituted the core, the response was "1."
- Statement 7. From the data-base printout of Statement 3, the code for

coal is 59, and the response was therefore "59." The computer output at this point consists of listings of the various connection orders appropriate to coal as a starting (core) material. In general, the search results obtained from Statement 7 provide the user with a basis for selecting one or more complexes for economic analysis and comparison through the procedure options that begin with Statement 9. In this example, several of the products identified by the search routine were of interest based upon locally important features (e.g., local markets, existing plants, etc.). These products are coke, methanol, formaldehyde, calcium carbide, phosgene, acetylene, and isoprene. At this point, merchant capacities in tons/year for each of these were determined for use in the economic analyses. The first levels of co-siting involved two separate complexes, one based upon a combination of coke, methanol, and formaldehyde only (designated as Complex C_5 and shown in Figure 3-3), and a second based upon a combination of calcium carbide, phosgene, acetylene, and isoprene only (designated as Complex C_6 and shown in Figure 3-4). The final level of co-siting was a complete complex (designated as Complex C_{56} and shown in Figure 3-5) that combined the two first-level complexes and produced all seven of the coal derivatives. Economic analyses were performed separately for each of these complexes in this example.

● Statement 8. The response was "no" since no other core was of interest at this point. If another core had been of interest, it could have been designated at this point and another search for co-siting candidates would have been made. Further, if the search based on coal had

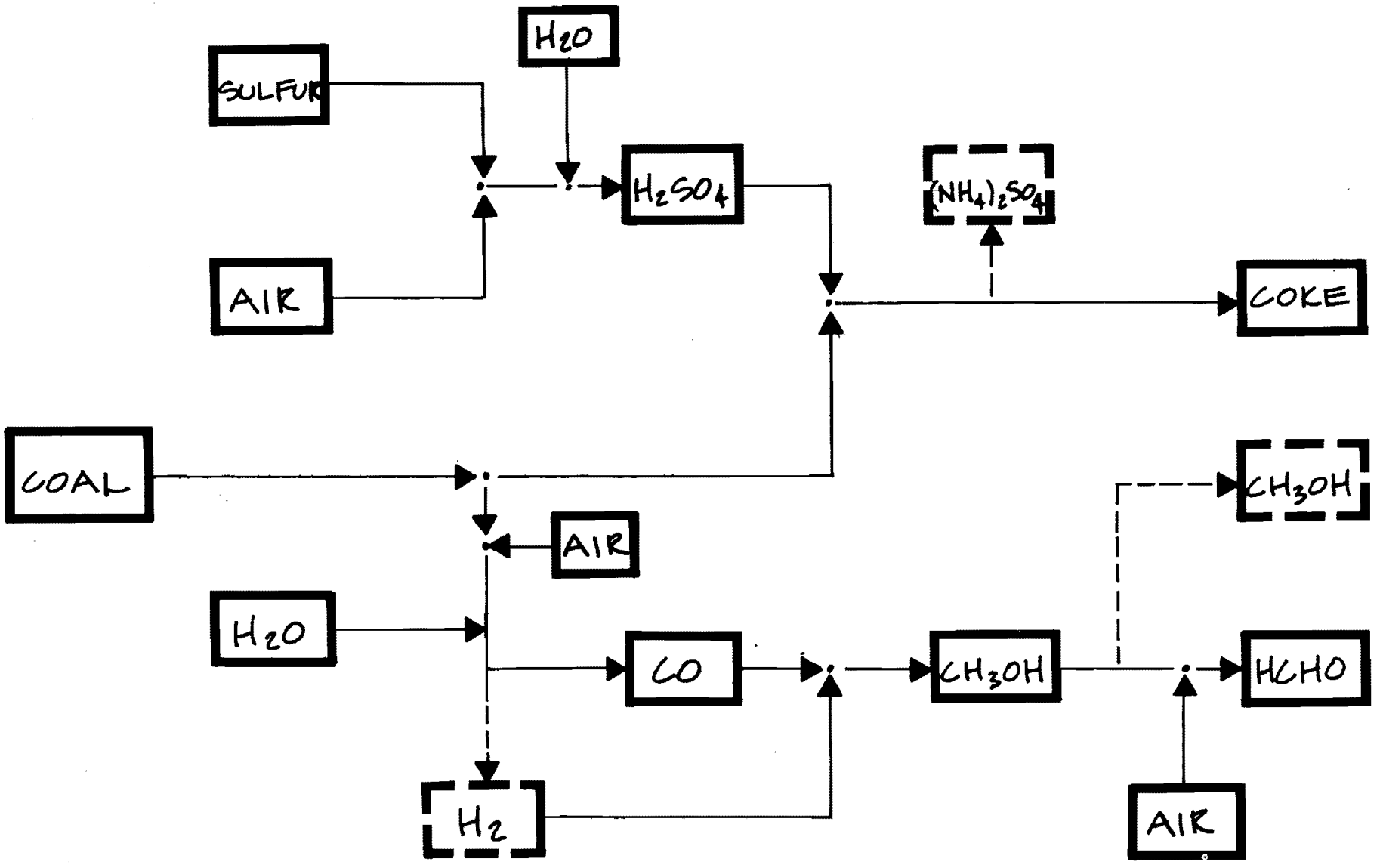


Figure 3-3. First Level of Co-siting of Operations Producing Coal Derivatives, Complex C_5.

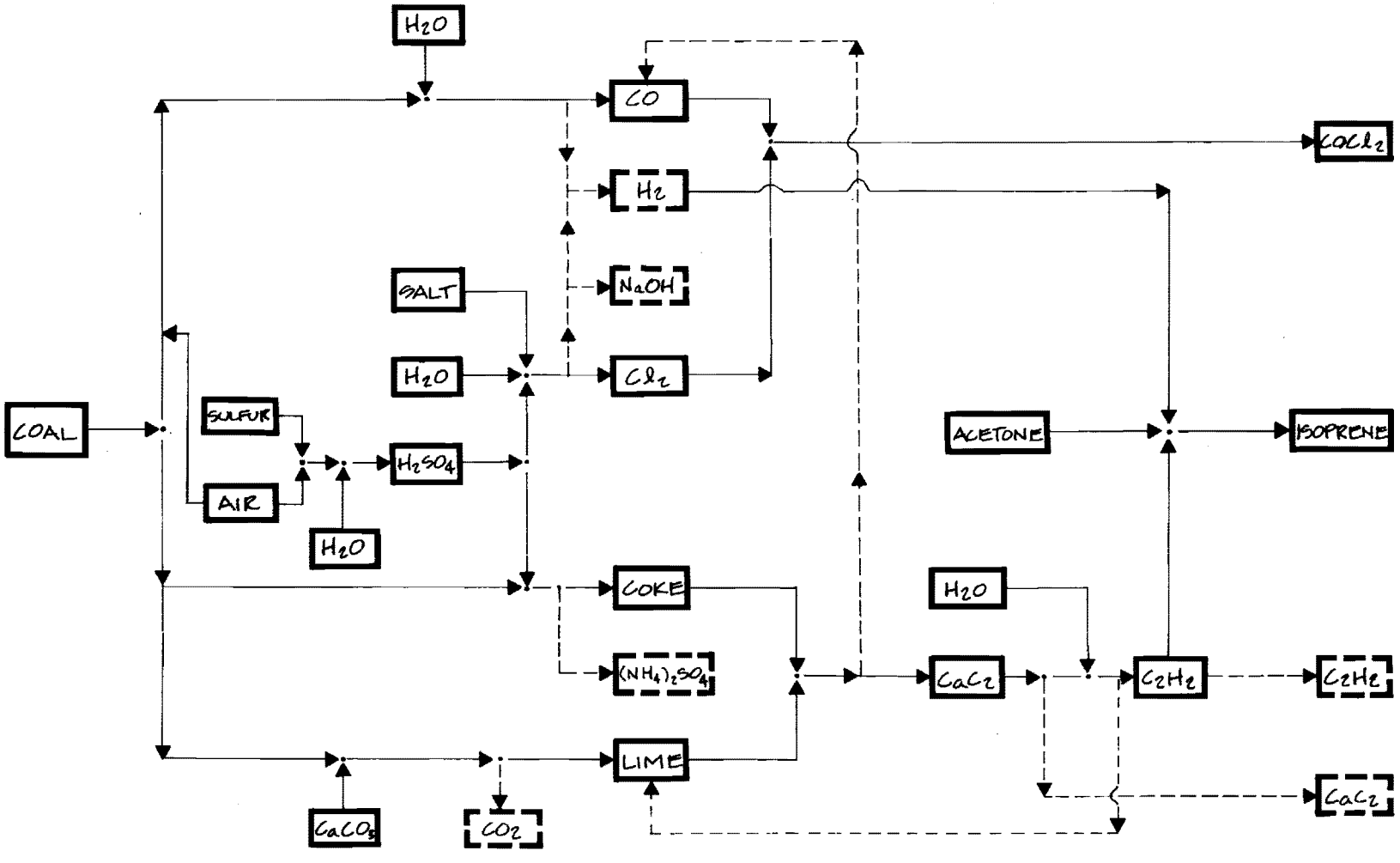


Figure 3-4. First Level of Co-siting of Operations Producing Coal Derivatives, Complex C_6.

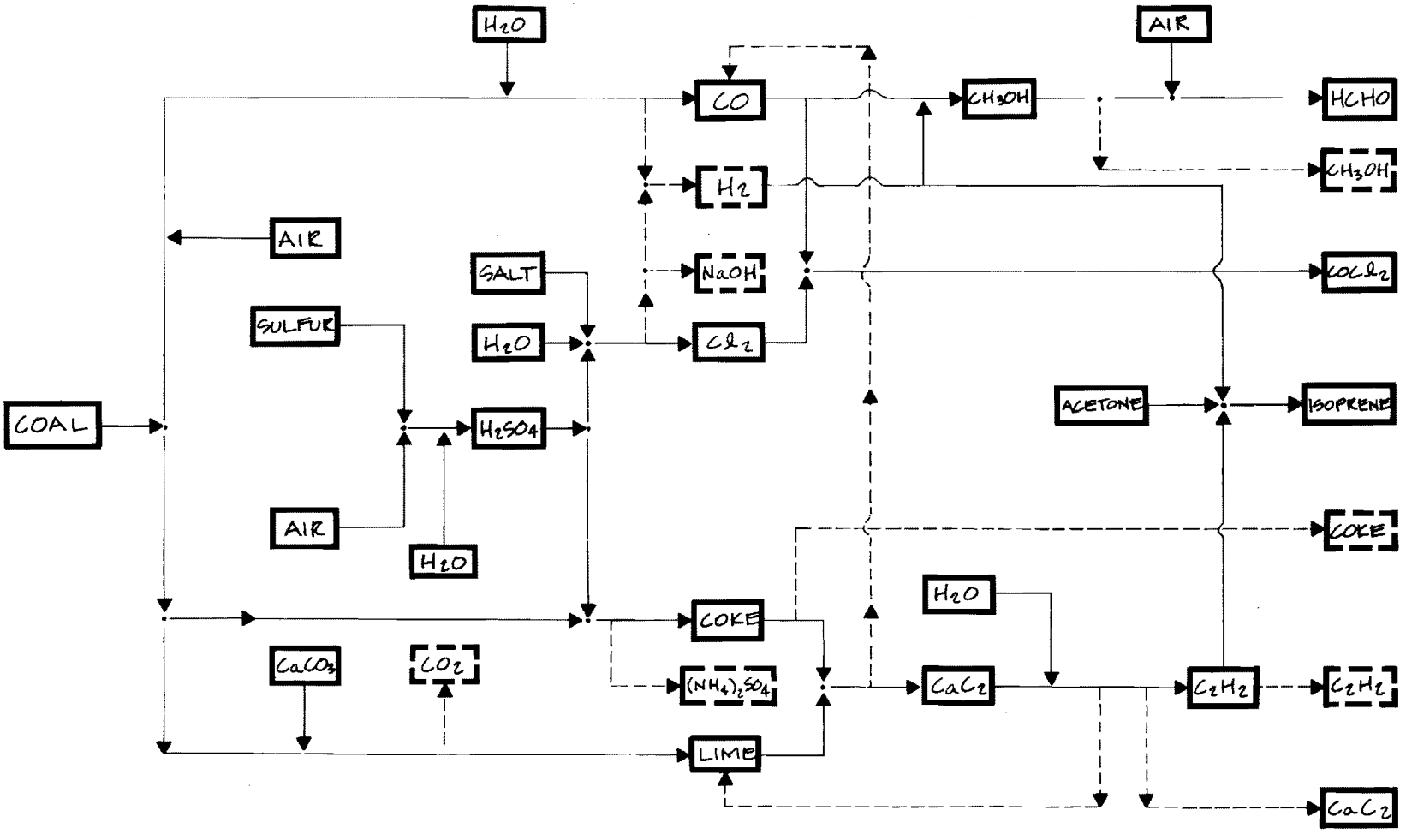


Figure 3-5. Second Level of Co-siting of Operations Producing Coal Derivatives, Complex C_{56}.

provided no candidates, a search for another core choice could have been made.

● Statement 9. The response was "yes," and Complex C_5 was the basis for the first economic analysis which begins with the response to Statement 10.

● Statement 10. Since there are three industries (coke, methanol, and formaldehyde) having merchant capacities in Complex C_5, the response was "3."

● Statement 11. The response was "70," "1000000"; "3," "300000"; "27," "150000." The respective code numbers were obtained from the data-base printout of Statement 3, and the merchant capacities are those selected to be relevant for these products as discussed under Statement 7 above.

● Statement 12. Since this illustrative example specified economic comparisons based on the Marshall-Stevens Index, the response was "1." Note that as pointed out in the computer printout for Statement 12, the user has two other options available to him.

● Statement 13A. Since the year specified in this illustrative example for the Marshall-Stevens Index was 1975, the response was "1975." At this point, economic analyses were printed by the computer for the isolated operations (when not co-sited) for comparison purposes and for the co-sited operations(Complex C_5). It should be noted that the capital costs, power requirements, etc., associated with each of the isolated operations shown in the economic analyses include all of the supporting plants as well (e.g., sulfuric acid plant, carbon monoxide plant, methanol plant, etc., as needed).

● Statement 14. Not desiring at this point to use any other basis for estimating plant costs, the response was "no."

- Statement 15A. Desiring now to analyze Complex C_6, the response was "yes."
- Statement 15B. Desiring to use the same plant-cost basis previously used, the response was "yes." This response recycled the procedure back to Statement 10 and appropriate information was then provided to the computer by the user for Complex C_6 in response to Statements 10, 11, and 14. Complex C_{56} was then analyzed by a repeat of this procedure.
- Statement 16. Having completed the desired analyses, the response was "no." This response automatically terminates the computer procedure.

The results of this entire example procedure permit the user to compare the relative cost benefits associated with the various levels of co-siting. Capital costs comparisons are summarized in Table 3-I.

Table 3-I. Capital Cost Comparisons Between Isolated Operations and Various Co-Siting Levels

Product	Isolated Operations		First Level of Co-Siting	Second Level of Co-Siting
	Capacity (tons/yr)	Cost* (MM$)	Cost* (MM$)	Cost* (MM$)
Coke	1,000,000	102.8		
Methanol	300,000	56.4	C_5 → 221.8	
Formaldehyde	150,000	80.1		C_{56} → 326.7
Calcium Carbide	100,000	36.9		
Phosgene	50,000	27.9	C_6 → 130.1	
Acetylene	50,000	55.3		
Isoprene	40,000	43.5		
		402.9	351.9	326.7

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

Section 3.2.2 Computer Printout for Illustrative Example

```
 THIS PROGRAM WAS DESIGNED AND COMPUTERIZED DURING
1976 AS PART OF A STUDY INVESTIGATING SYNERGISTIC
CO-SITING CONDUCTED BY THE ENGINEERING EXPERIMENT
STATION OF THE GEORGIA INSTITUTE OF TECHNOLOGY UNDER
CONTRACT TO THE APPALACHIAN REGIONAL COMMISSION,
WASHINGTON, D.C.

1. HAVE YOU USED THIS PROGRAM BEFORE ?
? NO

 SINCE THIS IS THE FIRST TIME YOU HAVE USED THIS
PROGRAM, IT IS RECOMMENDED THAT YOU PROCEED AS
FOLLOWS :

 (1) READ THE "GUIDELINES FOR SYNERGISTIC CO-SITING"
THAT HAS BEEN PREPARED AS A USER MANUAL FOR THIS
PROGRAM TO ACQUAINT YOU WITH ITS PURPOSE AND
PROCEDURAL GUIDELINES. THIS WILL CLARIFY THE STATE-
MENTS WHICH FOLLOW AND PROVIDE A BASIS FOR SELECTING
APPROPRIATE RESPONSES TO THESE STATEMENTS.

 (2) TYPE "YES" IN RESPONSE TO BOTH STATEMENTS 2 AND
3, WHICH FOLLOW. THE COMPUTER WILL THEN PROVIDE YOU
WITH A BRIEF REVIEW OF ESSENTIAL INFORMATION ABOUT
THE COMPUTER PROGRAM AND A LIST OF DATA BASE
INDUSTRIES AND RAW MATERIALS, WITH THEIR CODE
NUMBERS, FROM WHICH YOU MUST SELECT "CORE"
COMPONENTS OF CO-SITING GROUPINGS IN RESPONSE TO
SEVERAL OF THE STATEMENTS THAT FOLLOW. ALWAYS USE
THE APPROPRIATE CODE NUMBER FOR ITEMS OF INTEREST ON
THIS LIST WHEN RESPONDING TO SUCH STATEMENTS.
INDUSTRIES OR MATERIALS THAT ARE NOT ON THIS LIST
CANNOT NOW BE CONSIDERED AS POTENTIAL CANDIDATE
COMPONENTS OF CO-SITING GROUPINGS IN THE ANALYSIS
WHICH THIS PROGRAM ACCOMPLISHES.

2. DO YOU WANT A DESCRIPTION OF THIS PROGRAM ?
? YES
```

THIS PROGRAM INVOLVES AN INTERROGATIVE-CONVERSATIONAL FORMAT WHICH UTILIZES PROCEDURAL AND EXPLANATORY STEPS THAT ARE TAILORED FOR THE EXPERIENCE LEVEL OF THE INDIVIDUAL USER. RESPONSES SELECTED BY THE USER FOR EACH OF THE QUESTIONS OR GUIDELINE STATEMENTS DETERMINE THE SEQUENCE OF FURTHER STEPS IN THE PROCEDURAL FORMAT.

THE OVERALL FUNCTIONS PERFORMED FOR THE USER BY THE PROGRAM ARE ACCOMPLISHED IN THREE MAJOR GROUPINGS OF 16 STATEMENTS :

GROUP 1 (STATEMENTS 1-4) PROVIDES THE USER WITH BACKGROUND INFORMATION RELATING TO STEPS IN THE PROGRAM AND ITEMS IN THE DATA BASE.

GROUP 2 (STATEMENTS 5-8) PROVIDES FOR A SEARCH FOR CO-SITING CANDIDATES AND PRINTS CONNECTIONS OF VARIOUS ORDERS. THE USER IS REQUIRED TO PROVIDE A "CORE" WHICH MAY CONSIST OF ONE OR MORE OF THE CHEMICAL COMMODITIES LISTED IN THE DATA BASE. THE PRINTOUT CONSISTS OF ITEMS LISTED UNDER "COMPONENT 1" (THE CORE ITEMS SPECIFIED BY THE USER) AND "COMPONENT 2" (ITEMS THAT MATCH WITH THE CORE ITEMS AND WOULD BE APPROPRIATE POTENTIAL CO-SITING CANDIDATES.)

GROUP 3 (STATEMENTS 9-16) PROVIDES FOR ECONOMIC ANALYSIS OF CO-SITING GROUPINGS (COMPLEXES) SELECTED BY THE USER FROM THE CANDIDATES IDENTIFIED BY THE GROUP 2 PROCEDURE.

ABBREVIATIONS USED IN THE COMPUTER PRINTOUT, AND THEIR MEANINGS, ARE AS FOLLOWS :

```
          TPY = TONS PER YEAR
          MM$ = MILLIONS OF DOLLARS
        MM$PY = MILLIONS OF DOLLARS PER YEAR
           MW = MEGAWATTS (OF POWER CONSUMED)
```

FOR A THOROUGH EXPLANATION OF THE TERMS "ORDER OF CONNECTION" AND "CORE", USED IN GROUP 2 STATEMENTS AND PRINTOUTS, AND "MERCHANT CAPACITIES", "CAPTIVE PRODUCTION", "MERCHANT PRODUCTION", "TOTAL PRODUCTION", "PLANT COST", "PRODUCT VALUE", "RAW MATERIAL COST", "BY-PRODUCT CREDIT", "POWER", AND "REMARKS", USED IN GROUP 3 STATEMENTS AND PRINTOUTS, REFER TO "GUIDELINES FOR SYNERGISTIC CO-SITING" THAT HAS BEEN PREPARED AS A USER MANUAL FOR THIS PROGRAM.

3. DO YOU WANT A LIST OF THE 88 INDUSTRIES
   INCLUDED IN THE DATA BASE OF THIS PROGRAM ?
? YES

NO.	INDUSTRY NAME	NO.	INDUSTRY NAME
1	ETHYLENE	2	OXYGEN
3	METHANOL	4	CARBON MONOXIDE
* 5	PROPYLENE	6	AMMONIA
7	CHLORINE	8	BENZENE
* 9	HYDROGEN	* 10	HYDROGEN CHLORIDE
11	ACETALDEHYDE	12	ACETIC ACID
13	ACRYLONITRILE	* 14	ACETONITRILE
* 15	HYDROGEN CYANIDE	16	AMMONIUM NITRATE
17	CUMENE	18	PHENOL
* 19	ACETONE	20	BIS-PHENOL A
21	CYCLOHEXANE	22	ETHANOL
23	ETHYLENE OXIDE	24	MONO-ETHANOL AMINE
25	ETHYLBENZENE	26	ETHYL ACETATE
27	FORMALDEHYDE	28	ISOPROPANOL
29	MALEIC ANHYDRIDE	30	METHYL CHLORIDE
31	NITRIC ACID	32	ETHYLENE DICHLORID
33	PERCHLOROETHYLENE	34	PERACETIC ACID
35	POLYETHYLENE	* 36	BTX FRACTION
* 37	TOLUENE	38	POLYPROPYLENE
39	ETHYLENE GLYCOL	40	STYRENE
41	POLYSTYRENE	42	PROPYLENE OXIDE
43	TETRAHYDROFURAN	* 44	CARBON DIOXIDE
45	UREA	46	VINYL ACETATE
47	VINYL CHLORIDE	48	POLYVINYL CHLORIDE
** 49	ETHANE	** 50	PROPANE
51	ISOPRENE	* 52	NITROGEN
* 53	SODIUM CHLORIDE	* 54	SODIUM HYDROXIDE
* 55	O-XYLENE	* 56	M-XYLENE
* 57	P-XYLENE	** 58	CALCIUM CARBONATE
** 59	COAL	60	ANILINE
61	PHTHALIC ANHYDRIDE	62	TEREPHTHALIC ACID
63	SULFURIC ACID	64	SODIUM CHLORATE
65	MELAMINE	66	ACETIC ANHYDRIDE
67	ACETYLENE	68	CALCIUM CARBIDE
69	CALCIUM OXIDE	70	COKE
* 71	TRICHLOROETHYLENE	* 72	AMMONIUM SULFATE
73	AMMONIUM CHLORIDE	74	NITROBENZENE
75	BENZOIC ACID	* 76	BUTADIENE
77	ETHYL ETHER	78	ETHYL CHLORIDE
79	SODIUM HYPOCHLORIT	80	HYDRAZINE
81	METHYL METHACRYLAT	** 82	SULFUR
83	PHOSGENE	84	SODIUM
* 85	SODIUM SULFATE	* 86	ISO-BUTANE
* 87	TERT-BUTYL ALCOHOL	** 88	SODIUM CARBONATE

* BY-PRODUCTS ONLY
** RAW MATERIALS ONLY

4. DO YOU WANT A LIST OF SOURCES OF DESCRIPTIVE
   INFORMATION FOR INDUSTRIES IN THE DATA BASE ?
? YES

(A) F. A. LOWENHEIM AND M. K. MORAN, "FAITH, KEYES AND CLARK'S INDUSTRIAL CHEMICALS", 4TH EDITION, WILEY, NEW YORK (1975)

(B) R. N. SHREVE, "CHEMICAL PROCESS INDUSTRIES" 3RD EDITION, MCGRAW HILL, NEW YORK (1967)

(C) "CHEMICAL ORIGINS AND MARKETS", STANFORD RESEARCH INSTITUTE (1967)

(D) J. A. KENT, "RIEGEL'S HANDBOOK OF INDUSTRIAL CHEMISTRY", 7TH EDITION, VAN NOSTRAND, NEW YORK (1974)

5. WOULD YOU LIKE TO PERFORM A SEARCH FOR CO-SITING CANDIDATES FOR A SPECIFIC CORE OF INDUSTRIES ?
? YES

6. HOW MANY INDUSTRIES CONSTITUTE THE CORE OF THE COMPLEX YOU ARE CONSIDERING ? (THE CORE MAY CONSIST OF NEW INDUSTRIES ONLY, EXISTING INDUSTRIES ONLY, OR BOTH NEW AND EXISTING INDUSTRIES.)
? 1

7. LIST THE CODES OF THE INDUSTRIES IN THE CORE
? 59

SUMMARY OF CONNECTIONS OF ORDER 1

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	CARBON MONOXIDE	COAL	CALCIUM OXIDE
COAL	COKE		

SUMMARY OF CONNECTIONS OF ORDER 2

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	METHANOL	COAL	HYDROGEN
COAL	CARBON DIOXIDE	COAL	CALCIUM CARBONATE
COAL	SULFURIC ACID	COAL	ACETYLENE
COAL	CALCIUM CARBIDE	COAL	AMMONIUM SULFATE
COAL	PHOSGENE		

SUMMARY OF CONNECTIONS OF ORDER 3

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	AMMONIA	COAL	CHLORINE
COAL	CYCLOHEXANE	COAL	ETHYLENE OXIDE
COAL	FORMALDEHYDE	COAL	MALEIC ANHYDRIDE
COAL	METHYL CHLORIDE	COAL	TETRAHYDROFURAN
COAL	UREA	COAL	ISOPRENE
COAL	SODIUM CHLORATE	COAL	MELAMINE
COAL	AMMONIUM CHLORIDE	COAL	ETHYL ETHER
COAL	METHYL METHACRYLAT	COAL	SULFUR

SUMMARY OF CONNECTIONS OF ORDER 4

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	ETHYLENE	COAL	OXYGEN
COAL	BENZENE	COAL	HYDROGEN CHLORIDE
COAL	ACRYLONITRILE	COAL	HYDROGEN CYANIDE
COAL	AMMONIUM NITRATE	COAL	ACETONE
COAL	ETHANOL	COAL	MONO-ETHANOL AMINE
COAL	NITRIC ACID	COAL	ETHYLENE DICHLORID
COAL	PERCHLOROETHYLENE	COAL	ETHYLENE GLYCOL
COAL	NITROGEN	COAL	SODIUM CHLORIDE
COAL	SODIUM HYDROXIDE	COAL	ANILINE
COAL	SODIUM HYPOCHLORIT	COAL	HYDRAZINE
COAL	SODIUM	COAL	SODIUM SULFATE

SUMMARY OF CONNECTIONS OF ORDER 5

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	PROPYLENE	COAL	ACETALDEHYDE
COAL	ACETONITRILE	COAL	CUMENE
COAL	PHENOL	COAL	BIS-PHENOL A
COAL	ETHYLBENZENE	COAL	ETHYL ACETATE
COAL	PERACETIC ACID	COAL	POLYETHYLENE
COAL	BTX FRACTION	COAL	TOLUENE
COAL	STYRENE	COAL	PROPYLENE OXIDE
COAL	VINYL ACETATE	COAL	VINYL CHLORIDE
COAL	ETHANE	COAL	PROPANE
COAL	O-XYLENE	COAL	M-XYLENE
COAL	P-XYLENE	COAL	TRICHLOROETHYLENE
COAL	NITROBENZENE	COAL	BUTADIENE
COAL	ETHYL CHLORIDE	COAL	ISO-BUTANE

SUMMARY OF CONNECTIONS OF ORDER 6

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	ACETIC ACID	COAL	ISOPROPANOL
COAL	POLYPROPYLENE	COAL	POLYSTYRENE
COAL	POLYVINYL CHLORIDE	COAL	PHTHALIC ANHYDRIDE
COAL	TEREPHTHALIC ACID	COAL	BENZOIC ACID
COAL	TERT-BUTYL ALCOHOL	COAL	SODIUM CARBONATE

SUMMARY OF CONNECTIONS OF ORDER 7

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	ACETIC ANHYDRIDE		

CONNECTIONS OF HIGHER ORDERS ARE NOT UNIQUE

8. AT THIS POINT WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF INDUSTRIES AND BEGIN ANOTHER SEARCH FOR CO-SITING CANDIDATES FOR THIS CORE ?
? NO

9. WOULD YOU LIKE TO PERFORM AN ECONOMIC ANALYSIS FOR A SPECIFIC COMPLEX ?
? YES

10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU SPECIFY MERCHANT CAPACITIES ?
? 3

11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE COMPLEX AND THEIR MERCHANT CAPACITIES, I.E., INDUSTRY NUMBER, CAPACITY (TONS/YEAR)
? 70,1000000
? 3, 300000
? 27, 150000

12. SEVERAL OPTIONS ARE AVAILABLE FOR THE ANNUAL INCREASE IN THE COST OF CHEMICAL PLANTS. INCORPORATED IN THIS COMPUTER PROGRAM, AS OPTION (1), FOR THIS RATE OF INCREASE IS THE AVERAGE MARSHALL-STEVENS INDEX FOR THE YEAR 1975, WITH AN ALLOWANCE FOR AN ANNUAL AVERAGE INCREASE OF 4.5 PERCENT FOR YEARS BEYOND 1975 IN WHICH A PLANT MIGHT BE CONSTRUCTED. OPTION (2) PROVIDES FOR THE SPECIFICATION OF ANY MARSHALL-STEVENS INDEX OF INTEREST. OPTION (3) IS A MODIFICATION OF OPTION (1) WHICH USES THE MARSHALL-STEVENS INDEX INCORPORATED IN THE PROGRAM FOR THE YEAR 1975, BUT PERMITS THE USER TO SPECIFY AN ANNUAL INCREASE OTHER THAN 4.5 PERCENT BEYOND THE 1975 INDEX VALUE.

TYPE IN THE OPTION YOU PREFER
? 1

13A. TYPE IN THE YEAR OF INTEREST (OPTION 1 ONLY)
? 1975

ISOLATED OPERATIONS PRODUCING COKE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
59	COAL	1429000.0	0	1429000.0			28.580			RAW MATERIAL
63	SULFURIC ACID	18000.0	0	18000.0	.504				.011	
70	COKE	0.0	1000000	1000000.0	102.319	40.000			1.310	
72	AMMONIUM SULFATE	-18000.0	0	-18000.0				.720		BY-PRODUCT
82	SULFUR	6192.0	0	6192.0			.780			RAW MATERIAL
	TOTAL				102.823	40.000	29.360	.720	1.320	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING METHANOL

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	0.0	300000	300000.0	26.822	36.420			4.286	
4	CARBON MONOXIDE	438900.0	0	438900.0	29.536				15.675	
9	HYDROGEN	5226.3	0	5226.3			.209			RAW MATERIAL
59	COAL	235250.4	0	235250.4			4.705			RAW MATERIAL
	TOTAL				56.358	36.420	4.914	0.000	19.961	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING FORMALDEHYDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	0	188550.0	19.288				2.694	
4	CARBON MONOXIDE	275848.7	0	275848.7	21.339				9.852	
9	HYDROGEN	3284.7	0	3284.7			.131			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
59	COAL	147854.9	0	147854.9			2.957			RAW MATERIAL
	TOTAL				80.147	36.480	3.088	0.000	16.117	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

CO-SITED OPERATIONS (COMPLEX)

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	300000	488550.0	37.919	36.420			6.979	
4	CARBON MONOXIDE	714748.7	0	714748.7	41.554				25.527	
9	HYDROGEN	8511.0	0	8511.0			.340			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
59	COAL	1812105.3	0	1812105.3			36.242			RAW MATERIAL
63	SULFURIC ACID	18000.0	0	18000.0	.504				.011	
70	COKE	0.0	1000000	1000000.0	102.319	40.000			1.310	
72	AMMONIUM SULFATE	-18000.0	0	-18000.0				.720		BY-PRODUCT
82	SULFUR	6192.0	0	6192.0			.780			RAW MATERIAL
	TOTAL				221.816	112.900	37.363	.720	37.398	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH
A DIFFERENT ANNUAL INCREASE IN PLANT COSTS ?
? NO

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR
ANOTHER COMPLEX ?
? YES

15B. DO YOU WANT TO USE THE SAME PLANT-COST BASIS IN
THIS ANALYSIS YOU CHOSE IN RESPONSE TO
STATEMENTS 12 AND 13 IN THE PREVIOUS ANALYSIS?
? YES

10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU
SPECIFY MERCHANT CAPACITIES ?
? 4

11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE
COMPLEX AND THEIR MERCHANT CAPACITIES, I.E.,
INDUSTRY NUMBER, CAPACITY (TONS/YEAR)
? 68,100000
? 83, 50000
? 67, 50000
? 51, 40000

ISOLATED OPERATIONS PRODUCING CALCIUM CARBIDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-48000.0	0	-48000.0				1.920		BY-PRODUCT
44	CARBON DIOXIDE	-77298.0	0	-77298.0				1.546		BY-PRODUCT
58	CALCIUM CARBONATE	188290.0	0	188290.0			.941			RAW MATERIAL
59	COAL	127330.7	0	127330.7			2.547			RAW MATERIAL
63	SULFURIC ACID	1229.4	0	1229.4	.081				.001	
68	CALCIUM CARBIDE	0.0	100000	100000.0	19.814	17.140			34.524	
69	CALCIUM OXIDE	99100.0	0	99100.0	1.390				.295	
70	COKE	68300.0	0	68300.0	15.633				.089	
72	AMMONIUM SULFATE	-1229.4	0	-1229.4				.049		BY-PRODUCT
82	SULFUR	422.9	0	422.9			.053			RAW MATERIAL
	TOTAL				36.918	17.140	3.541	3.515	34.909	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING PHOSGENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	14400.0	0	14400.0	2.701				.514	
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	-2923.2	0	-2923.2				.117		BY-PRODUCT
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
59	COAL	7718.4	0	7718.4			.154			RAW MATERIAL
63	SULFURIC ACID	360.0	0	360.0	.035				.000	
82	SULFUR	123.8	0	123.8			.016			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				27.854	25.000	3.108	15.844	14.562	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ACETYLENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-72048.0	0	-72048.0				2.882		BY-PRODUCT
44	CARBON DIOXIDE	-32018.3	0	-32018.3				.640		BY-PRODUCT
58	CALCIUM CARBONATE	77993.3	0	77993.3			.390			RAW MATERIAL
59	COAL	158813.4	0	158813.4			3.176			RAW MATERIAL
63	SULFURIC ACID	1845.3	0	1845.3	.107				.001	
67	ACETYLENE	0.0	50000	50000.0	7.335	49.000			1.190	
68	CALCIUM CARBIDE	150100.0	0	150100.0	26.329				51.820	
69	CALCIUM OXIDE	41049.1	0	41049.1	.750				.122	
70	COKE	102518.3	0	102518.3	20.774				.134	
72	AMMONIUM SULFATE	-1845.3	0	-1845.3				.074		BY-PRODUCT
82	SULFUR	634.8	0	634.8			.080			RAW MATERIAL
	TOTAL				55.296	49.000	3.646	3.596	53.268	

* CAPITAL COSTS ONLY, NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ISOPRENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-25649.1	0	-25649.1				1.026		BY-PRODUCT
9	HYDROGEN	18800.0	0	18800.0			.752			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
44	CARBON DIOXIDE	-11398.5	0	-11398.5				.228		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
58	CALCIUM CARBONATE	27765.6	0	27765.6			.139			RAW MATERIAL
59	COAL	56537.6	0	56537.6			1.131			RAW MATERIAL
63	SULFURIC ACID	656.9	0	656.9	.053				.000	
67	ACETYLENE	17800.0	0	17800.0	3.560				.424	
68	CALCIUM CARBIDE	53435.6	0	53435.6	12.778				18.448	
69	CALCIUM OXIDE	14613.5	0	14613.5	.364				.043	
70	COKE	36496.5	0	36496.5	10.082				.048	
72	AMMONIUM SULFATE	-656.9	0	-656.9				.026		BY-PRODUCT
82	SULFUR	226.0	0	226.0			.028			RAW MATERIAL
	TOTAL				43.545	56.000	14.050	1.280	21.821	

* CAPITAL COSTS ONLY, NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

CO-SITED OPERATIONS (COMPLEX)

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-131297.1	0	-131297.1				5.252		BY-PRODUCT
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	17792.0	0	17792.0			.712			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
44	CARBON DIOXIDE	-120714.8	0	-120714.8				2.414		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
58	CALCIUM CARBONATE	294048.9	0	294048.9			1.470			RAW MATERIAL
59	COAL	342681.6	0	342681.6			6.854			RAW MATERIAL
63	SULFURIC ACID	4091.7	0	4091.7	.184				.002	
67	ACETYLENE	17800.0	50000	67800.0	9.078	49.000			1.614	
68	CALCIUM CARBIDE	203535.6	100000	303535.6	43.104	17.140			104.792	
69	CALCIUM OXIDE	154762.6	0	154762.6	1.899				.461	
70	COKE	207314.8	0	207314.8	34.009				.271	
72	AMMONIUM SULFATE	-3731.7	0	-3731.7				.149		BY-PRODUCT
82	SULFUR	1407.5	0	1407.5			.177			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				130.101	147.140	24.151	23.542	124.046	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH
A DIFFERENT ANNUAL INCREASE IN PLANT COSTS ?
? NO

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR
ANOTHER COMPLEX ?
? YES

15B. DO YOU WANT TO USE THE SAME PLANT-COST BASIS IN
THIS ANALYSIS YOU CHOSE IN RESPONSE TO
STATEMENTS 12 AND 13 IN THE PREVIOUS ANALYSIS?
? YES

10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU
SPECIFY MERCHANT CAPACITIES ?
? 7

11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE
COMPLEX AND THEIR MERCHANT CAPACITIES, I.E.,
INDUSTRY NUMBER, CAPACITY (TONS/YEAR)
? 70,1000000
? 3, 300000
? 27, 150000
? 68, 100000
? 83, 50000
? 67, 50000
? 51, 40000

ISOLATED OPERATIONS PRODUCING COKE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
59	COAL	1429000.0	0	1429000.0			28.580			RAW MATERIAL
63	SULFURIC ACID	18000.0	0	18000.0	.504				.011	
70	COKE	0.0	1000000	1000000.0	102.319	40.000			1.310	
72	AMMONIUM SULFATE	-18000.0	0	-18000.0				.720		BY-PRODUCT
82	SULFUR	6192.0	0	6192.0			.780			RAW MATERIAL
	TOTAL				102.823	40.000	29.360	.720	1.320	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING METHANOL

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	0.0	300000	300000.0	26.822	36.420			4.286	
4	CARBON MONOXIDE	438900.0	0	438900.0	29.536				15.675	
9	HYDROGEN	5226.3	0	5226.3			.209			RAW MATERIAL
59	COAL	235250.4	0	235250.4			4.705			RAW MATERIAL
	TOTAL				56.358	36.420	4.914	0.000	19.961	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING FORMALDEHYDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	0	188550.0	19.288				2.694	
4	CARBON MONOXIDE	275848.7	0	275848.7	21.339				9.852	
9	HYDROGEN	3284.7	0	3284.7			.131			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
59	COAL	147854.9	0	147854.9			2.957			RAW MATERIAL
	TOTAL				80.147	36.480	3.088	0.000	16.117	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING CALCIUM CARBIDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-48000.0	0	-48000.0				1.920		BY-PRODUCT
44	CARBON DIOXIDE	-77298.0	0	-77298.0				1.546		BY-PRODUCT
58	CALCIUM CARBONATE	188290.0	0	188290.0			.941			RAW MATERIAL
59	COAL	127330.7	0	127330.7			2.547			RAW MATERIAL
63	SULFURIC ACID	1229.4	0	1229.4	.081				.001	
68	CALCIUM CARBIDE	0.0	100000	100000.0	19.814	17.140			34.524	
69	CALCIUM OXIDE	99100.0	0	99100.0	1.390				.295	
70	COKE	68300.0	0	68300.0	15.633				.089	
72	AMMONIUM SULFATE	-1229.4	0	-1229.4				.049		BY-PRODUCT
82	SULFUR	422.9	0	422.9			.053			RAW MATERIAL
	TOTAL				36.918	17.140	3.541	3.515	34.909	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING PHOSGENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	14400.0	0	14400.0	2.701				.514	
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	-2923.2	0	-2923.2				.117		BY-PRODUCT
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
59	COAL	7718.4	0	7718.4			.154			RAW MATERIAL
63	SULFURIC ACID	360.0	0	360.0	.035				.000	
82	SULFUR	123.8	0	123.8			.016			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				27.854	25.000	3.108	15.844	14.562	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ACETYLENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-72048.0	0	-72048.0				2.882		BY-PRODUCT
44	CARBON DIOXIDE	-32018.3	0	-32018.3				.640		BY-PRODUCT
58	CALCIUM CARBONATE	77993.3	0	77993.3			.390			RAW MATERIAL
59	COAL	158813.4	0	158813.4			3.176			RAW MATERIAL
63	SULFURIC ACID	1845.3	0	1845.3	.107				.001	
67	ACETYLENE	0.0	50000	50000.0	7.335	49.000			1.190	
68	CALCIUM CARBIDE	150100.0	0	150100.0	26.329				51.820	
69	CALCIUM OXIDE	41049.1	0	41049.1	.750				.122	
70	COKE	102518.3	0	102518.3	20.774				.134	
72	AMMONIUM SULFATE	-1845.3	0	-1845.3				.074		BY-PRODUCT
82	SULFUR	634.8	0	634.8			.080			RAW MATERIAL
	TOTAL				55.296	49.000	3.646	3.596	53.268	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ISOPRENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-25649.1	0	-25649.1				1.026		BY-PRODUCT
9	HYDROGEN	18800.0	0	18800.0			.752			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
44	CARBON DIOXIDE	-11398.5	0	-11398.5				.228		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
58	CALCIUM CARBONATE	27765.6	0	27765.6			.139			RAW MATERIAL
59	COAL	56537.6	0	56537.6			1.131			RAW MATERIAL
63	SULFURIC ACID	656.9	0	656.9	.053				.000	
67	ACETYLENE	17800.0	0	17800.0	3.560				.424	
68	CALCIUM CARBIDE	53435.6	0	53435.6	12.778				18.448	
69	CALCIUM OXIDE	14613.5	0	14613.5	.364				.043	
70	COKE	36496.5	0	36496.5	10.082				.048	
72	AMMONIUM SULFATE	-656.9	0	-656.9				.026		BY-PRODUCT
82	SULFUR	226.0	0	226.0			.028			RAW MATERIAL
	TOTAL				43.545	56.000	14.050	1.280	21.821	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

CO-SITED OPERATIONS (COMPLEX)

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	300000	488550.0	37.919	36.420			6.979	
4	CARBON MONOXIDE	583451.6	0	583451.6	36.050				20.838	
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	43765.5	0	43765.5			1.751			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
44	CARBON DIOXIDE	-120714.8	0	-120714.8				2.414		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
58	CALCIUM CARBONATE	294048.9	0	294048.9			1.470			RAW MATERIAL
59	COAL	2084411.7	0	2084411.7			41.688			RAW MATERIAL
63	SULFURIC ACID	22091.7	0	22091.7	.579				.013	

67	ACETYLENE	17800.0	50000	67800.0	9.078	49.000			1.614	
68	CALCIUM CARBIDE	203535.6	100000	303535.6	43.104	17.140			104.792	
69	CALCIUM OXIDE	154762.6	0	154762.6	1.899				.461	
70	COKE	207314.8	1000000	1207314.8	116.743	40.000			1.581	
72	AMMONIUM SULFATE	-21731.7	0	-21731.7				.869		BY-PRODUCT
82	SULFUR	7599.5	0	7599.5			.958			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				326.719	260.040	60.805	19.010	156.754	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH
A DIFFERENT ANNUAL INCREASE IN PLANT COSTS ?
? NO

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR
ANOTHER COMPLEX ?
? NO

16. WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF
INDUSTRIES AND BEGIN ANOTHER SEARCH FOR
CO-SITING CANDIDATES FOR THIS CORE ?
? NO
45.883 CP SECONDS EXECUTION TIME
/

A-1742

Acceptance Test Report
Equipment Set 001
(Reworked)

TEST DATA

SYSTEM TESTS

A1742 SERIAL NO. 001

A. Background Noise:
(With AGCs grounded, measured at -500 Pin A5) 45 V P-P

B. Overall Signal Characteristics and Background Noise
(50Ω Gen)

Clutter AGC	-1.82 Volts
Gain Suppression	20 dB
Background Noise	≈6 V P-P

(Measured at -500 Pin A5)

Input Level vs. Output at Monitor Ports

Input Signal = -51 dBm @ -600 Pin A1 & A2

Monitor Ports Output @ -600 A5	0.25 V P-P
-700 A5	0.5 V P-P

Input Level = -71 dBm

-100 A5	0.2 V P-P

Input Level = -118 dBm

-400 A5	0.4 V P-P
-500 A4	4.0 V P-P
-500 A5	40 V P-P

Tested by:

Signature

Date: 10/6/76

TEST DATA

MODULE A1742-100 SERIAL NO. 001

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	8.200 MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.073 MHz	
1.5	Bandpass Marker 1 Frequency	9.957 MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	116 KHz	110-130 KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.815 MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	9% Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	55 dB	54-58 dB
1.13	Notch Upper 3 dB Frequency	10.0033 MHz	
1.14	Notch Lower 3 dB Frequency	9.9982 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	5.1 KHz	4.5 - 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.80 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	>60 dB	40 dB min
1.18	AGC Test Frequency (f signal - f_{LO})	1.815 MHz	

Tested by _____ Signature

Date 4 October 1976

TEST DATA

MODULE A1742-100 SERIAL NO. 001

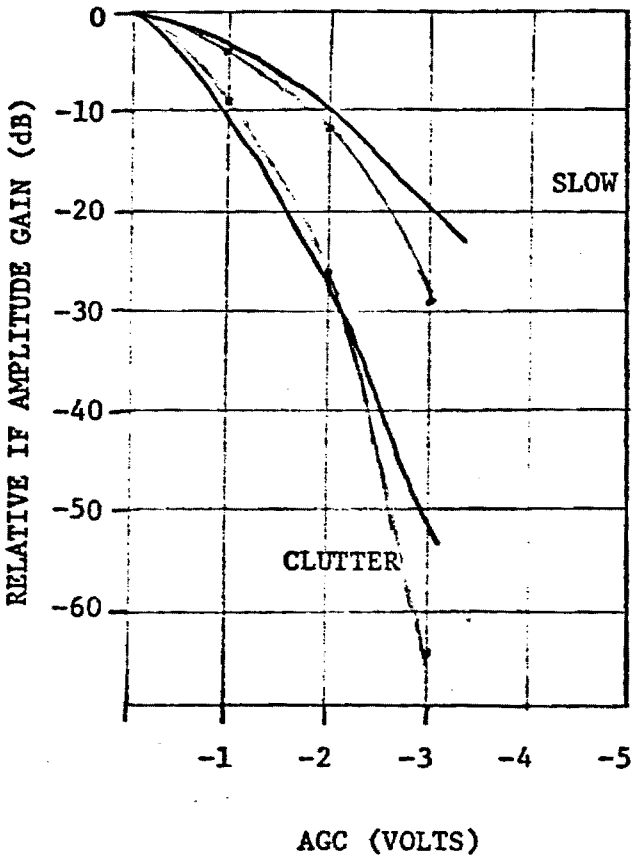
TEST		RESULT
1.19 Gain Reduction (Slow AGC = 0V)		
Clutter AGC =	-1.0 V	-9.5 dB
	-2.0 V	-26.5 dB
	-3.0 V	-64.5 dB
1.20 Gain Reduction (Clutter AGC = 0V)		
Slow AGC =	-1.0 V	-4.5 dB
=	-2.0 V	-11.5 dB
=	-3.0 V	-29 dB

Tested by _____
Signature

Date 1 Oct 76

TEST DATA

Module A1742-100 Serial No. 001



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.2 V
1.22 SLOW AGC	0.5 V

TESTED BY _____
SIGNATURE

DATE 1 Oct 76

TEST DATA

MODULE A1742-100 SERIAL NO. 001

TEST	RESULT
1.23 Bandpass Response Clutter AGC = -3V Slow AGC = -3V	
Local Oscillator Frequency	8.200 MHz
Bandpass Marker 2	10.081 MHz
Bandpass Marker 1	9.956 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	125 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.818 MHz

Tested by _____ Signature _____

Date 18 Oct 76

TEST DATA

MODULE A1742-200 SERIAL NO. 001

	TEST	RESULT		LIMITS
2.1	DC Resistance			
	Pins A1-2	9.2	Ohms	5-15 Ohms
	A1-GND	100	Ohms	100-120 Ohms
	A2-3	9.0	Ohms	5-15 Ohms
	A2-GND	100	Ohms	100-120 Ohms
	2-GND	90	Ohms	90-110 Ohms
	3-GND	95	Ohms	90-110 Ohms
2.2	Signal Output Level	✓	Check	1 Vpp Max
2.3	Bandpass Marker 2	10.216	MHz	
2.4	Bandpass Marker 1	9.485	MHz	
2.5	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	731	KHz	595-735 KHz
2.6	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.84	MHz	9.7 - 10.0 MHz
2.7	Dip at Center of Response Curve	0.4	dB	2 dB Max
2.8	Monitor Output (Percent of Signal Output)	✓ 120%	Check	100% nominal
2.9	Spurious Responses	✓	Check	
2.10	Overall Gain	31.5	dB	28-32 dB

Tested by _____
Signature

Date 4 Oct 1976

TEST DATA

MODULE A1742-200 SERIAL NO. 001

	TEST	RESULT
2.11	Bandpass Response, Gain Pot set for Max Gain	
	Bandpass Marker 2	10.206 MHz
	Bandpass Marker 1	9.472 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	734 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.83 MHz
2.12	Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
	Bandpass Marker 2	10.212 MHz
	Bandpass Marker 1	9.505 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	707 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.85 MHz

Tested by _____
Signature

Date 11 Oct 1016

TEST DATA

MODULE A1742-300 SERIAL NO. 001

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.800 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	2.8 Check	2.8 Vpp Nominal
3.3	Signal Output Level	0.6 ✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.339 MHz	
3.5	Frequency Marker 1	9.688 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	651 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{\text{(Marker 2)} \quad \text{(Marker 1)}} - f_{LO}$	8.208 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.3 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	✓ 10% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	42 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	6.3 Vpp	
	Input Voltage	135 mVpp	

Tested by _____
Signature

Date 10/4/76

TEST DATA

MODULES A1742-400 SERIAL NO. 001

A1742-500 SERIAL NO. 001

TEST	RESULT	LIMITS
4.1 Output Signal Level	✓ Check	8 V_{rms} Nominal (22 P-P)
4.2 Bandpass Upper 3 dB Frequency	250.29 KHz	
4.3 Bandpass Lower 3 dB Frequency	249.823 KHz	
4.4 Bandpass Bandwidth ($f_{Up} - f_{LO}$)	467 Hz	400-500 Hz
4.5 Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	250.056 KHz	250 KHz ± 200 Hz
4.6 Discriminator Response		
DC Output = 0 V	250.052 KHz	250 KHz ± 200 Hz
+1 V	249.991 KHz	
+2 V	249.946 KHz	
+3 V	249.909 KHz	
+4 V	249.885 KHz	
+5 V	249.——— KHz	
Positive Peak 4.9 V	249.858 KHz	
-1 V	250.115 KHz	
-2 V	250.174 KHz	
-3 V	250.212 KHz	
-4 V	250.235 KHz	
-5 V	250.——— KHz	

Tested by _____
Signature

Date 10/6/76

TEST DATA

MODULES A1742-400 SERIAL NO. 001

A1742-500 SERIAL NO. 001

TEST	RESULTS	LIMITS
Negative Peak		
−4.4 V	250.256 KHz	

4.7 See Discriminator Data Plot.

4.8 Monitor Outputs (Percent of Signal Output)

-400 pin A5	✓ 13% Check	15% Nominal
-500 pin A4	✓ 10.6% Check	10% Nominal
-500 pin A5	NOMINAL Check	100% Nominal

4.9 Gain Reduction

Fast AGC = -1.0 V	1.8 dB	
-2.0 V	6.0 dB	
-3.0 V	18 dB	
-4.0 V	41 dB	

4.10 See AGC data plot.

4.11 Local Oscillator

Frequency	1.57 MHz	1.5-1.6 MHz
Level	12 Vpp ✓ Check	12 Vpp Nominal

Tested by _____
Signature

Date 10/6/76

TEST DATA

MODULES A1742-400 SERIAL NO. 001

A1742-500 SERIAL NO. 001

	TEST	RESULT	LIMITS
4.12	No Data Required		
4.13	Spurious Responses	✓ Check	
4.14	Overall Gain	77.5 dB	70–76 dB

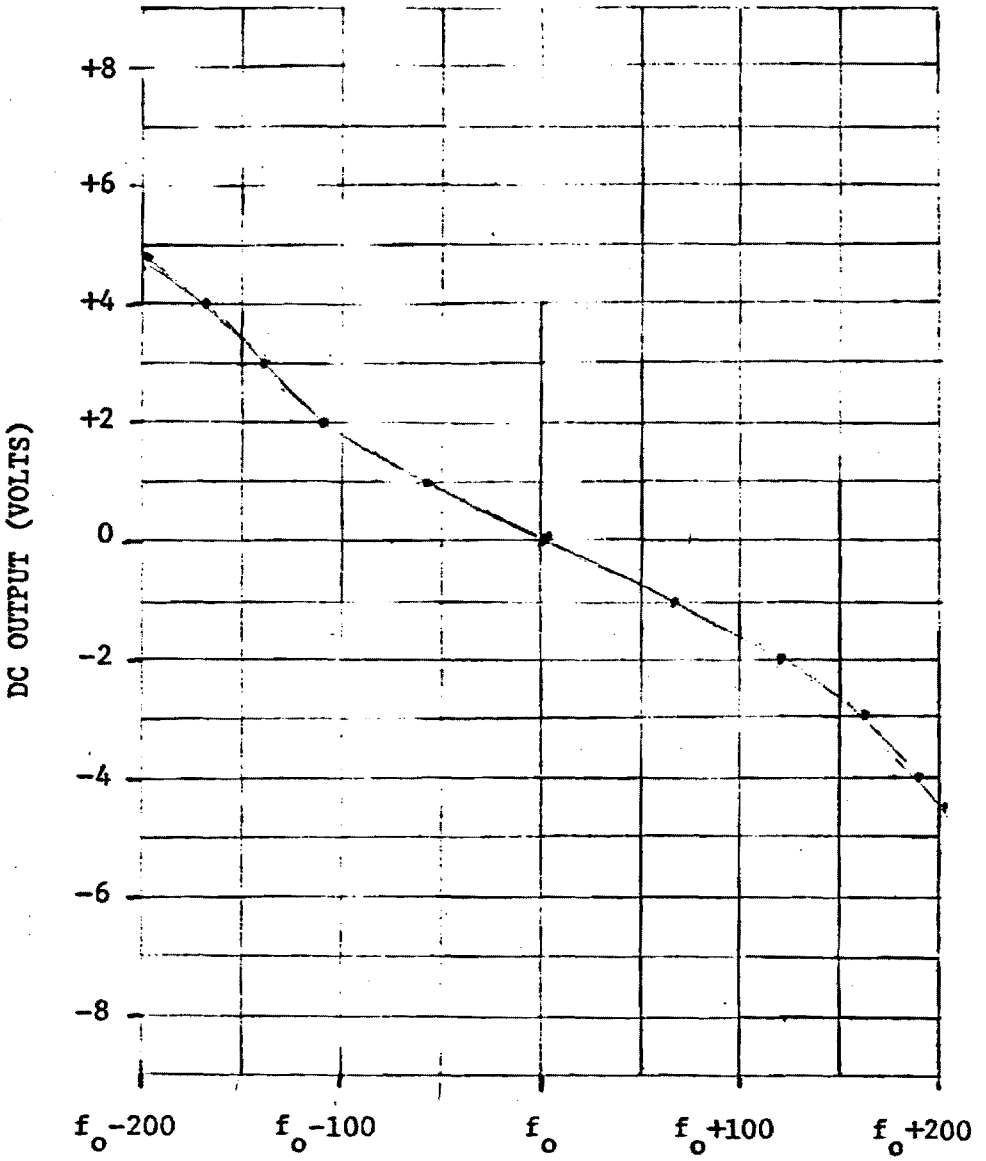
Tested by _____
Signature

Date 10/6/76

TEST DATA

MODULES A1742-400 SERIAL NO. 001

A1742-500 SERIAL NO. 001



f_o = 250.052 KHz

4.7 Discriminator Response

Tested by _____

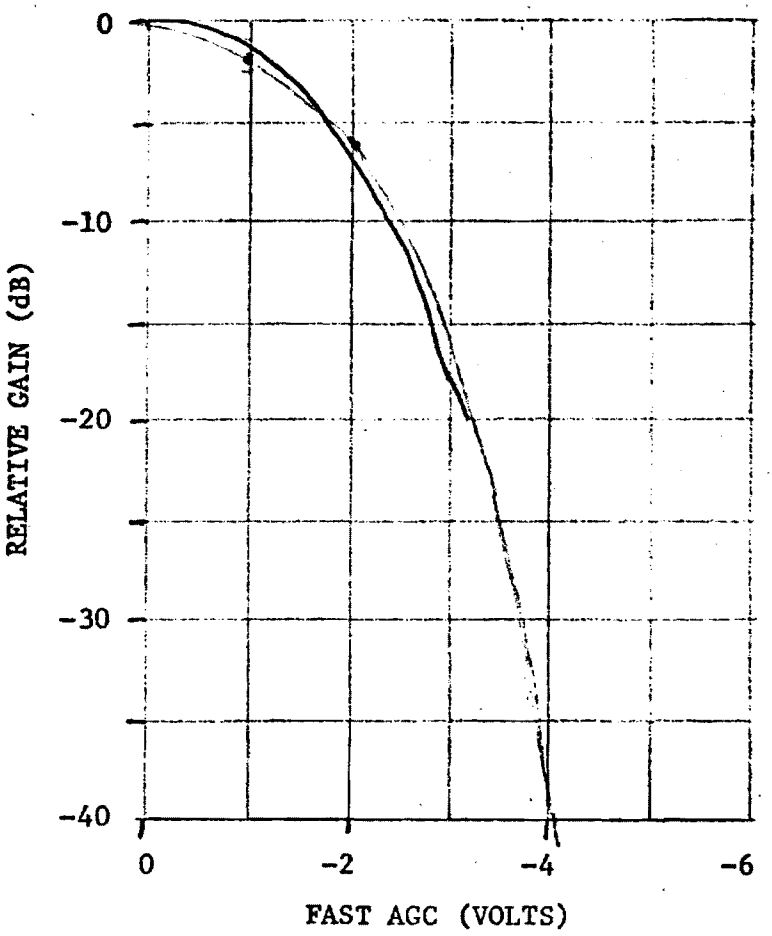
Signature

Dated 10/6/76

TEST DATA

MODULES A1742-400 SERIAL NO. 001

A1742-500 SERIAL NO. 001



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	0.1 V

TESTED BY _____
SIGNATURE

DATE 10/6/76

TEST DATA

MODULES A1742-400 SERIAL NO. 001

A1742-500 SERIAL NO. 001

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250.278 KHz
Bandpass Lower 3 dB Frequency	249.824 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	454 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.051 KHz

Tested by _____
Signature

Date 10/6/76

TEST DATA

MODULE A1742-600 SERIAL NO. 001

A1742-700 SERIAL NO. 001

TEST	RESULT	LIMITS
6.1 DC Resistance (-600 Module)		
Pins A1-2	10 Ohms	5-15 Ohms
A1-GND	111 Ohms	100-120 Ohms
A2-3	10 Ohms	5-15 Ohms
A2-GND	110 Ohms	100-120 Ohms
2-GND	101 Ohms	90-110 Ohms
3-GND	100 Ohms	90-110 Ohms
6.2 Signal Output Level	✓ Check	1 Vpp Max
6.3 Bandpass Marker 2	10.282 MHz	
6.4 Bandpass Marker 1	9.710 MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	572 KHz	485-585 KHz
6.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99 MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0 dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)		
-600	✓ 0.95 Check	1X A7 Output
-700	4.2 ✓ Check	7X A7 Output
6.9 Spurious Responses		
-600	✓ Check	
-700	✓ Check	

Tested by _____
Signature

Date 10/5/76

TEST DATA

MODULES A1742-600 SERIAL NO. 001

A1742-700 SERIAL NO. 001

TEST		RESULT	LIMITS
6.10 Overall Gain		10.5 dB	6-10 dB
6.11 Gain Reduction			
	Slow AGC = -1.0 V	3.7 dB	
	-2.0 V	10.4 dB	
	-3.0 V	26.0 dB	
	-3.5 V	40.0 dB	
6.12 AGC Symmetry		✓ Check	

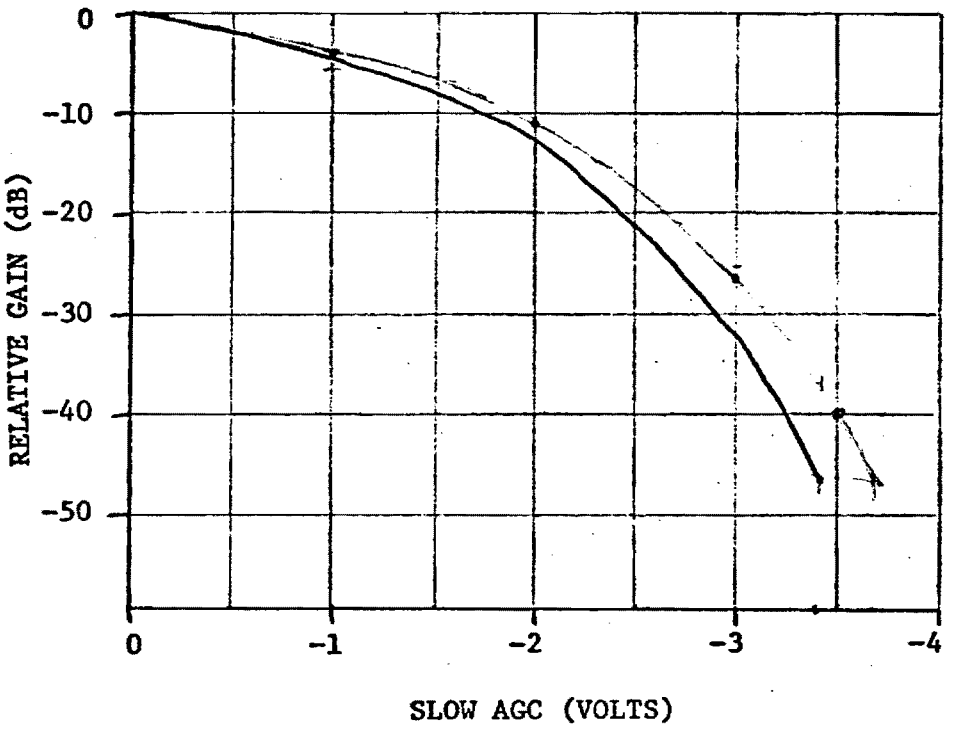
Tested by _____
Signature

Date 10/5/76

TEST DATA

MODULES A1742-600 SERIAL NO. 001

A1742-700 SERIAL NO. 001



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
6.13 SLOW AGC	0.3 V

TESTED BY _____
SIGNATURE

DATE 10/5/76

TEST DATA

MODULES A1742-600 SERIAL NO. 001

A1742-700 SERIAL NO. 001

	TEST	RESULT
6.14	Bandpass Response Slow AGC = -3V	
	Bandpass Marker 2	10.252 MHz
	Bandpass Marker 1	9.748 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	504 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99 MHz

Tested by _____
Signature

Date 10/5/76

Acceptance Test Report 2

A-1742

TEST DATA

MODULE A1742-100 SERIAL NO. 002

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	8.200 MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.072 MHz	
1.5	Bandpass Marker 1 Frequency	9.944 MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 − Marker 1)	128 KHz	110-130 KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.81 MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	8.3% Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	48.5 dB	48-52 dB
1.13	Notch Upper 3 dB Frequency	10.0024 MHz	
1.14	Notch Lower 3 dB Frequency	9.9970 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	5.4 KHz	4.5 − 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.800 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	>60 dB	40 dB min
1.18	AGC Test Frequency (f signal − f_{LO})	1.815 MHz	

Tested by _____
Signature

Date 28 June 76

TEST DATA

MODULE A1742-100 SERIAL NO. 002

TEST		RESULT
1.19 Gain Reduction (Slow AGC = 0V)		
Clutter AGC =	-1.0 V	-7.5 dB
	-2.0 V	-22.2 dB
	-3.0 V	-59 dB
1.20 Gain Reduction (Clutter AGC = 0V)		
Slow AGC =	-1.0 V	-2.2 dB
	= -2.0 V	-7 dB
	= -3.0 V	-15.2 dB

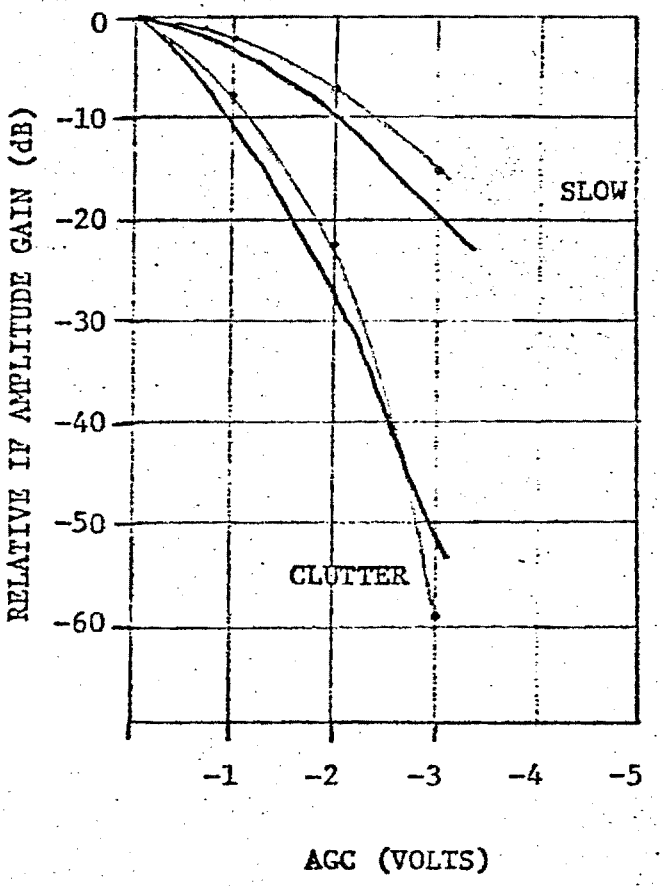
Tested by

Signature

Date 25 Jun 76

TEST DATA

Module A1742-100 Serial No. 002



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.2 V
1.22 SLOW AGC	0.5 V

TESTED BY [redacted]

DATE 25 June 76

TEST DATA

MODULE A1742-100 SERIAL NO. 002

TEST	RESULT
1.23 Bandpass Response Clutter AGC = -3V Slow AGC = -3V	
Local Oscillator Frequency	8.200 MHz
Bandpass Marker 2	10.058 MHz
Bandpass Marker 1	9.978 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	80 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.818 MHz

Tested by

Signature

Date 25 June 76

TEST DATA

MODULE A1742-200 SERIAL NO. 002

TEST	RESULT		LIMITS
2.1 DC Resistance			
Pins A1-2	9.5	Ohms	5-15 Ohms
A1-GND	105	Ohms	100-120 Ohms
A2-3	9.5	Ohms	5-15 Ohms
A2-GND	105	Ohms	100-120 Ohms
2-GND	95	Ohms	90-110 Ohms
3-GND	95	Ohms	90-110 Ohms
2.2 Signal Output Level	✓	Check	1 Vpp Max
2.3 Bandpass Marker 2	10.203	MHz	
2.4 Bandpass Marker 1	9.503	MHz	
2.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	700	KHz	595-735 KHz
2.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.846	MHz	9.7 - 10.0 MHz
2.7 Dip at Center of Response Curve	0	dB	2 dB Max
2.8 Monitor Output (Percent of Signal Output)	✓	Check	100% nominal
2.9 Spurious Responses	✓	Check	
2.10 Overall Gain	31	dB	28-32 dB

Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULE A1742-200 SERIAL NO. 002

TEST	RESULT
2.11 Bandpass Response, Gain Pot set for Max Gain	
Bandpass Marker 2	10.2008 MHz
Bandpass Marker 1	9.482 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	719 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.835 MHz
2.12 Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
Bandpass Marker 2	10.198 MHz
Bandpass Marker 1	9.549 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	649 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.868 MHz

Tested by __

Signature

Date 6/11/76

TEST DATA

MODULE A1742-300 SERIAL NO. 002

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.8 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	1V RMS Check	2.8 Vpp Nominal
3.3	Signal Output Level	✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.347 MHz	
3.5	Frequency Marker 1	9.685 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	662 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})\quad(\text{Marker 1})} - f_{LO}$	8.21 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.67 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	✓ 10% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	39 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	4.4 Vpp	
	Input Voltage	160 mVpp	

Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULES A1742-400 SERIAL NO. 002

A1742-500 SERIAL NO. 002

TEST	RESULT	LIMITS
4.1 Output Signal Level	✓ Check	8 V_{rms} Nominal
4.2 Bandpass Upper 3 dB Frequency	250.266 KHz	
4.3 Bandpass Lower 3 dB Frequency	249.793 KHz	
4.4 Bandpass Bandwidth ($f_{Up} - f_{LO}$)	473 Hz	400-500 Hz
4.5 Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	250.029 KHz	250 KHz ± 200 Hz
4.6 Discriminator Response		
DC Output = 0 V	250.032 KHz	250 KHz ± 200 Hz
+1 V	249.987 KHz	
+2 V	249.938 KHz	
+3 V	249.884 KHz	
+4 V	249.843 KHz	
+5 V	249.826 KHz	
Positive Peak 5.8 V	249.810 KHz	
-1 V	250.070 KHz	
-2 V	250.116 KHz	
-3 V	250.168 KHz	
-4 V	250.194 KHz	
~~-4.8~~ -5 V	250.222 KHz	

Tested by

Signature

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 002

A1742-500 SERIAL NO. 002

TEST	RESULTS	LIMITS
Negative Peak		
−4.8 V	250.222 KHz	
4.7 See Discriminator Data Plot.		
4.8 Monitor Outputs (Percent of Signal Output)		
−400 pin A5	≈10% ✓ Check	15% Nominal
−500 pin A4	10% ✓ Check	10% Nominal
−500 pin A5	100% ✓ Check	100% Nominal
4.9 Gain Reduction		
Fast AGC = −1.0 V	−1.2 dB	
−2.0 V	−4.4 dB	
−3.0 V	−12.5 dB	
−4.0 V	−33.5 dB	
4.10 See AGC data plot.		
4.11 Local Oscillator		
Frequency	1.550 MHz	1.5–1.6 MHz
Level	✓ Check	12 Vpp Nominal

Tested by _____
Signature

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 002

A1742-500 SERIAL NO. 002

TEST	RESULT	LIMITS
4.12 No Data Required		
4.13 Spurious Responses	✓ Check	
4.14 Overall Gain	74 dB	70-76 dB

Tested by

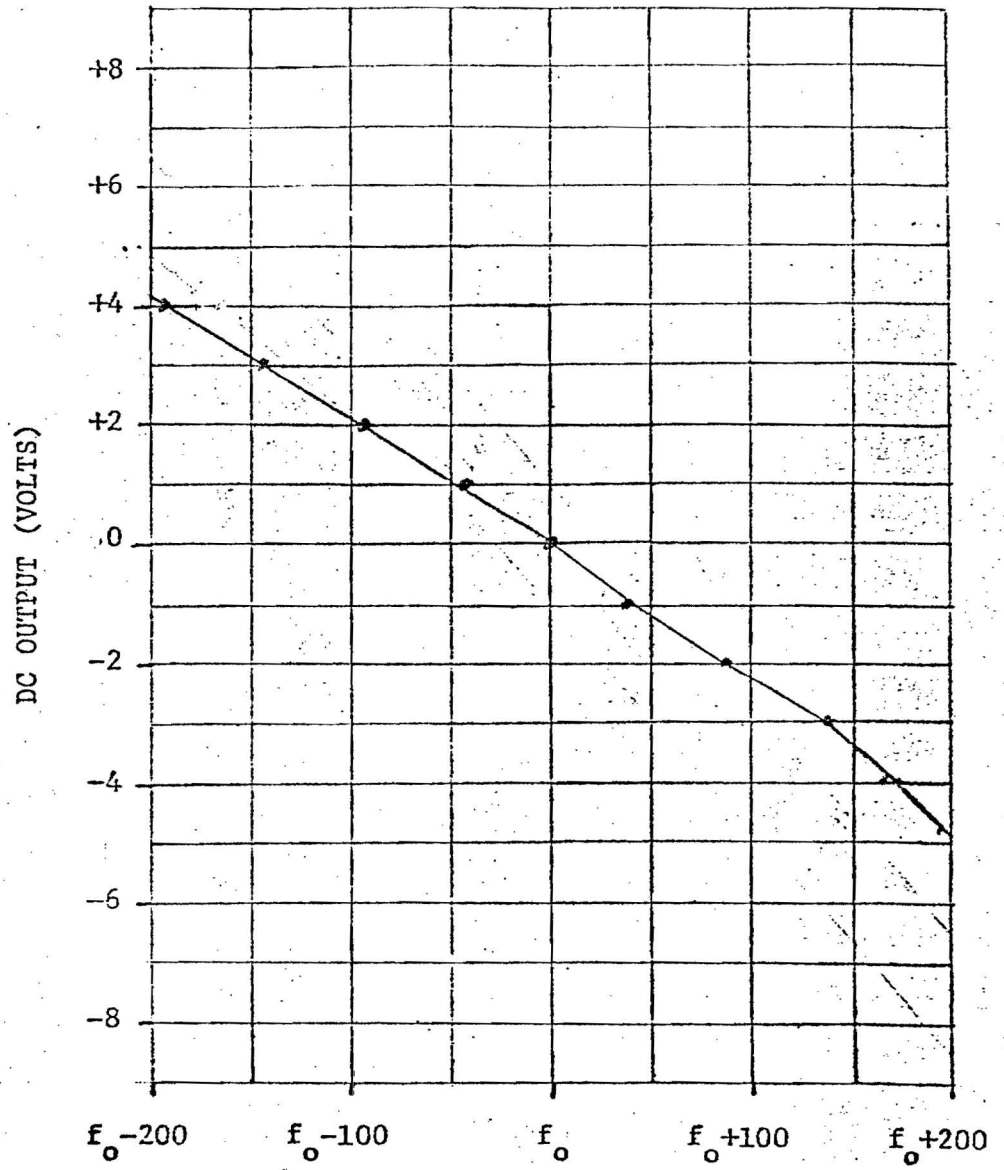
Signature

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 002

A1742-500 SERIAL NO. 002



f_o = 250,032 KHz

4.7 Discriminator Response

Tested by

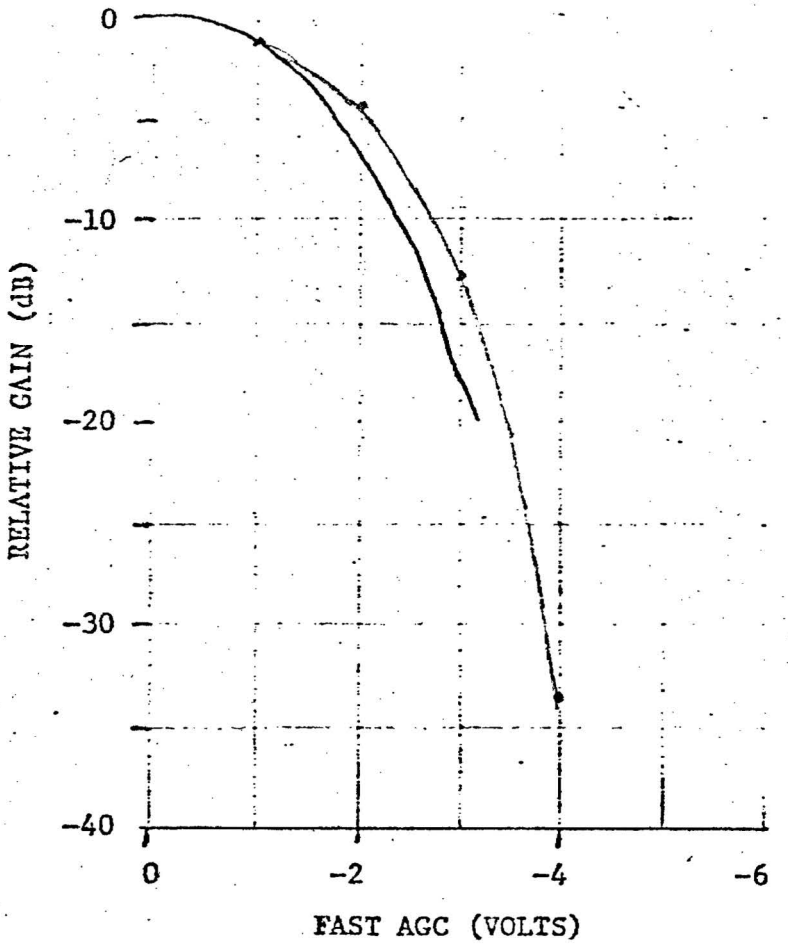
Signature

Dated 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 002

A1742-500 SERIAL NO. 002



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	0.3 V

TESTED BY _____
SIGNATURE

DATE 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 002

A1742-500 SERIAL NO. 002

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250.268 KHz
Bandpass Lower 3 dB Frequency	249.790 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	478 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.029 KHz

Tested by

Signature

Date 28 June 76

TEST DATA

MODULE A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002

TEST	RESULT	LIMITS
6.1 DC Resistance (-600 Module)		
Pins A1-2	9.5 Ohms	5-15 Ohms
A1-GND	100 Ohms	100-120 Ohms
A2-3	9.9 Ohms	5-15 Ohms
A2-GND	100 Ohms	100-120 Ohms
2-GND	100 Ohms	90-110 Ohms
3-GND	90 Ohms	90-110 Ohms
6.2 Signal Output Level	✓ Check	1 Vpp Max
6.3 Bandpass Marker 2	10.252 MHz	
6.4 Bandpass Marker 1	9.753 MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	499 KHz	485-585 KHz
6.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	10.000 MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0 dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)		
-600	✓ Check	1X Nominal
-700	5X Check	7X Nominal
6.9 Spurious Responses		
-600	✓ Check	
-700	✓ Check	

Tested by _____
Signature

Date 6/7/76

TEST DATA

MODULES A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002

TEST		RESULT	LIMITS
6.10 Overall Gain		11.0 dB	8-12 dB
6.11 Gain Reduction			
	Slow AGC = -1.0 V	-4.5 dB	
	-2.0 V	-12.5 dB	
	-3.0 V	-21.5 dB	
	-3.5 V	-25.5 dB	
6.12 AGC Symmetry		✓ Check	

Tested by _____

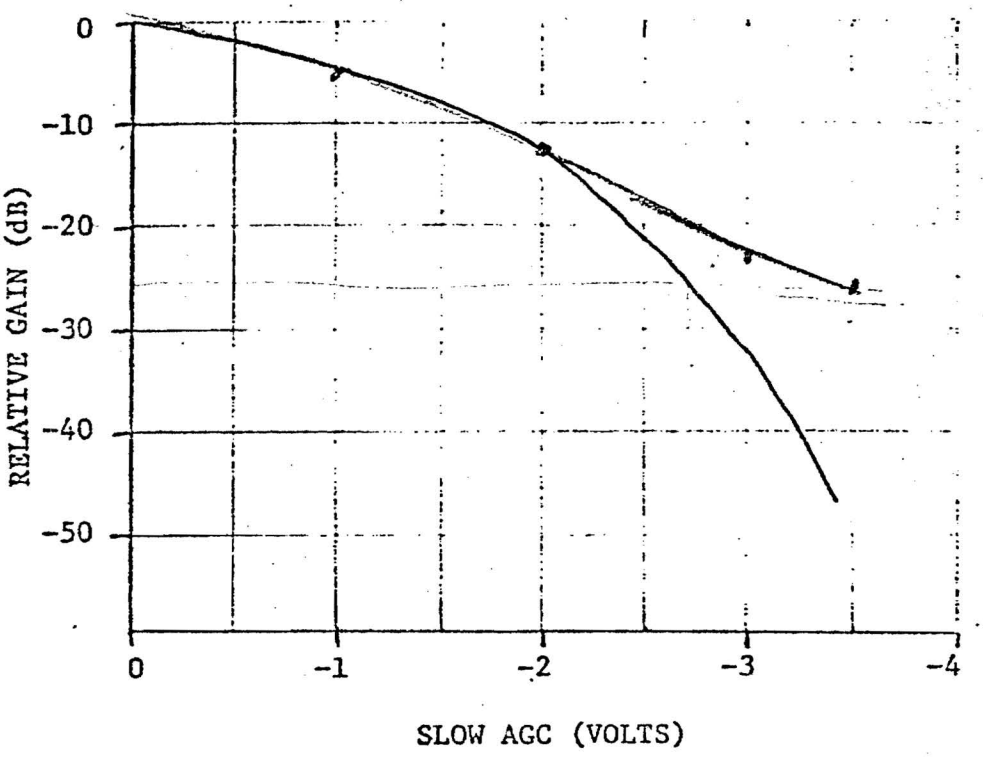
Signature

Date 6/7/76

TEST DATA

MODULES A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
6.13 SLOW AGC	-1.8 V @ -25db

TESTED BY _____
SIGNATURE

DATE 6/7/76

TEST DATA

MODULES A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002

TEST	RESULT
6.14 Bandpass Response Slow AGC = -3V	
Bandpass Marker 2	10.23060 MHz
Bandpass Marker 1	9.76472 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	466 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.995 MHz

Tested by _____
Signature

Date 6/7/76

TEST DATA

MODULE A1742-800 SERIAL NO. 002

VCXO SERIAL NO. 2

TEST	RESULT	
8.1 Output Voltage and Frequency	1 Vrms Nominal	(1.8 MHz @ 0V +40 KHz @ -10V -40 KHz @ +10V Nominal)

Tuning Voltage (V)	Output Voltage (V)	Frequency (MHz)
-10	0.88	1.843
-8	0.90	1.834
-6	0.91	1.826
-4	0.92	1.817
-2	0.93	1.809
0	0.94	1.800
+2	0.94	1.791
+4	0.94	1.782
+6	0.94	1.774
+8	0.92	1.765
+10	0.88	1.756

8.2 Output Waveform ✓ Check

OVEN WAS ON DURING TESTS.

Tested by _____
Signature

Date 6-29-76

Acceptance Test Data

A-1742

TEST DATA

SYSTEM TESTS

A1742 SERIAL NO. 002

A. Background Noise:
(With AGCs grounded, measured at -500 Pin A5) .40 V P-P

B. Overall Signal Characteristics and Background Noise
(50Ω Gen)

Clutter AGC	-1.75 Volts
Gain Suppression	20 dB
Background Noise	≈5 V P-P

(Measured at -500 Pin A5)

Input Level vs. Output at Monitor Ports

Input Signal = -46 dBm @ -600 Pin A1 & A2

Monitor Ports Output @ -600 A5	.044 V P-P
-700 A5	0.5 V P-P
Input Level = -66 dBm "	
-100 A5	0.2 V P-P
Input Level = -114 dBm "	
-400 A5	0.4 V P-P
-500 A4	4.0 V P-P
-500 A5	40 V P-P

TESTED BY DPN

DATE 8-31-76

TEST DATA

MODULE A1742-100 SERIAL NO. 002 MODIFIED

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	8.200 MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.067 MHz	
1.5	Bandpass Marker 1 Frequency	9.960 MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	107 KHz	100-130 ~~110-130~~ KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.81 MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	8.3% Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	57 dB	54-58 dB
1.13	Notch Upper 3 dB Frequency	10.00283 MHz	
1.14	Notch Lower 3 dB Frequency	9.99700 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	5.83 KHz	4.5 - 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.800 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	>60 dB	40 dB min
1.18	ACC Test Frequency (f signal - f_{LO})	1.813 MHz	

Tested by _____
Signature

Date 8-30-76

TEST DATA

MODULE A1742-100 SERIAL NO. 002 Modified

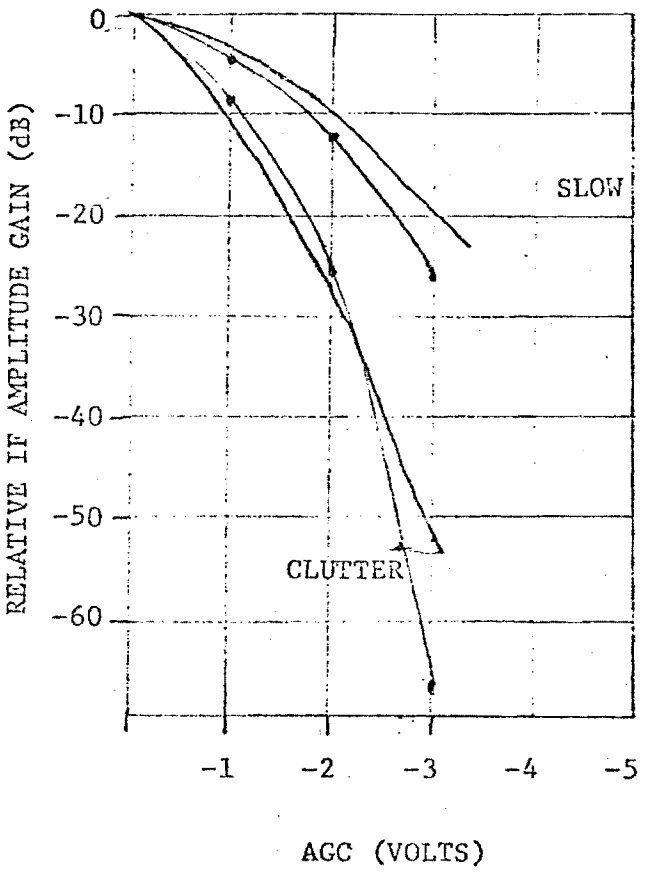
TEST		RESULT
1.19 Gain Reduction (Slow AGC = 0V)		
Clutter AGC =	-1.0 V	-8.8 dB
	-2.0 V	-26 dB
	-3.0 V	-67 dB
1.20 Gain Reduction (Clutter AGC = 0V)		
Slow AGC =	-1.0 V	-4.8 dB
=	-2.0 V	-12 dB
=	-3.0 V	-26.7 dB

Tested by DPN
Signature

Date 8-30-76

TEST DATA

Module A1742-100 Serial No. 002 MODIFIED



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.3 V
1.22 SLOW AGC	0.4 V

TESTED BY DPN
SIGNATURE

DATE 8-30-76

TEST DATA

MODULE A1742-100 SERIAL NO. 002 MODIFIED

TEST	RESULT
1.23 Bandpass Response Clutter AGC = -3V Slow AGC = -3V	
Local Oscillator Frequency	8.2 MHz
Bandpass Marker 2	10.070 MHz
Bandpass Marker 1	9.976 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	94 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.823 MHz

Tested by DPN
Signature

Date 8-30-76

TEST DATA

MODULE A1742-200 SERIAL NO. 002

TEST	RESULT	LIMITS
2.1 DC Resistance		
Pins A1-2	9.5 Ohms	5-15 Ohms
A1-GND	105 Ohms	100-120 Ohms
A2-3	9.5 Ohms	5-15 Ohms
A2-GND	105 Ohms	100-120 Ohms
2-GND	95 Ohms	90-110 Ohms
3-GND	95 Ohms	90-110 Ohms
2.2 Signal Output Level	✓ Check	1 Vpp Max
2.3 Bandpass Marker 2	10.257 MHz	
2.4 Bandpass Marker 1	9.545 MHz	
2.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	712 KHz	595-735 KHz
2.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.89 MHz	9.7 - 10.0 MHz
2.7 Dip at Center of Response Curve	-1.2 dB	2 dB Max
2.8 Monitor Output (Perce t of Signal Output)	100% Check	100% nominal
2.9 Spurious Responses	✓ Check	
2.10 Overall Gain	32 dB	28-32 dB

Tested by _____
Signature

Date 8-31-76

TEST DATA

MODULE A1742-200 SERIAL NO. 002

	TEST	RESULT
2.11	Bandpass Response, Gain Pot set for Max Gain	
	Bandpass Marker 2	10.248 MHz
	Bandpass Marker 1	9.530 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	768 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.88 MHz
2.12	Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
	Bandpass Marker 2	10.246 MHz
	Bandpass Marker 1	9.597 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	649 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.916 MHz

Tested by DPN
Signature

Date 8-31-76

TEST DATA

MODULE A1742-300 SERIAL NO. 004

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.8 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	1v RMS Check	2.8 Vpp Nominal
3.3	Signal Output Level	✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.340 MHz	
3.5	Frequency Marker 1	9.741 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	599 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})\ (\text{Marker 1})} - f_{LO}$	8.24 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.6 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	10% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	47 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	7 Vpp	
	Input Voltage	100 mVpp	

Tested by _____
Signature

Date 8-31-76

TEST DATA

MODULES A1742-400 SERIAL NO. 002 MODIFIED

A1742-500 SERIAL NO. 002 "

	TEST	RESULT	LIMITS
4.1	Output Signal Level	✓ Check	8 V_{rms} Nominal
4.2	Bandpass Upper 3 dB Frequency	250.247 KHz	
4.3	Bandpass Lower 3 dB Frequency	249.832 KHz	
4.4	Bandpass Bandwidth ($f_{Up} - f_{LO}$)	415 Hz	400-500 Hz
4.5	Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	250.039 KHz	250 KHz ± 200 Hz
4.6	Discriminator Response		
	DC Output = 0 V	250.028 KHz	250 KHz ± 200 Hz
	+1 V	249.990 KHz	
	+2 V	249.952 KHz	
	+3 V	249.913 KHz	
	+4 V	249.867 KHz	
	+5 V	249.827 KHz	
	Positive Peak		
	5.1 V	249.815 KHz	
	-1 V	250.063 KHz	
	-2 V	250.098 KHz	
	-3 V	250.143 KHz	
	-4 V	250.174 KHz	
	-5 V	250.201 KHz	

CONT'D

Tested by _____
Signature

Date 8-30-16

TEST DATA

MODULES A1742-400 SERIAL NO. 002 IDENT

A1742-500 SERIAL NO. 002 "

TEST	RESULTS	LIMITS
Negative Peak		
−5.3 V	250.223 KHz	
4.7 See Discriminator Data Plot.		
4.8 Monitor Outputs (Percent of Signal Output)		
-400 pin A5	≈ 10% Check	15% Nominal
-500 pin A4	10% Check	10% Nominal
-500 pin A5	100% Check	100% Nominal
4.9 Gain Reduction		
Fast AGC = -1.0 V	−1.5 dB	
-2.0 V	−5.3 dB	
-3.0 V	−16.1 dB	
-4.0 V	−40.5 dB	
4.10 See AGC data plot.		
4.11 Local Oscillator		
Frequency	____ MHz	1.5-1.6 MHz
Level	✓ Check	12 Vpp Nominal

Tested by DPN
Signature

Date 8-30-76

TEST DATA

MODULES A1742-400 SERIAL NO. 002 [illegible]

A1742-500 SERIAL NO. 002 "

TEST		RESULT	LIMITS
4.12	No Data Required		
4.13	Spurious Responses	✓ Check	
4.14	Overall Gain	76.5 dB	70-76 dB

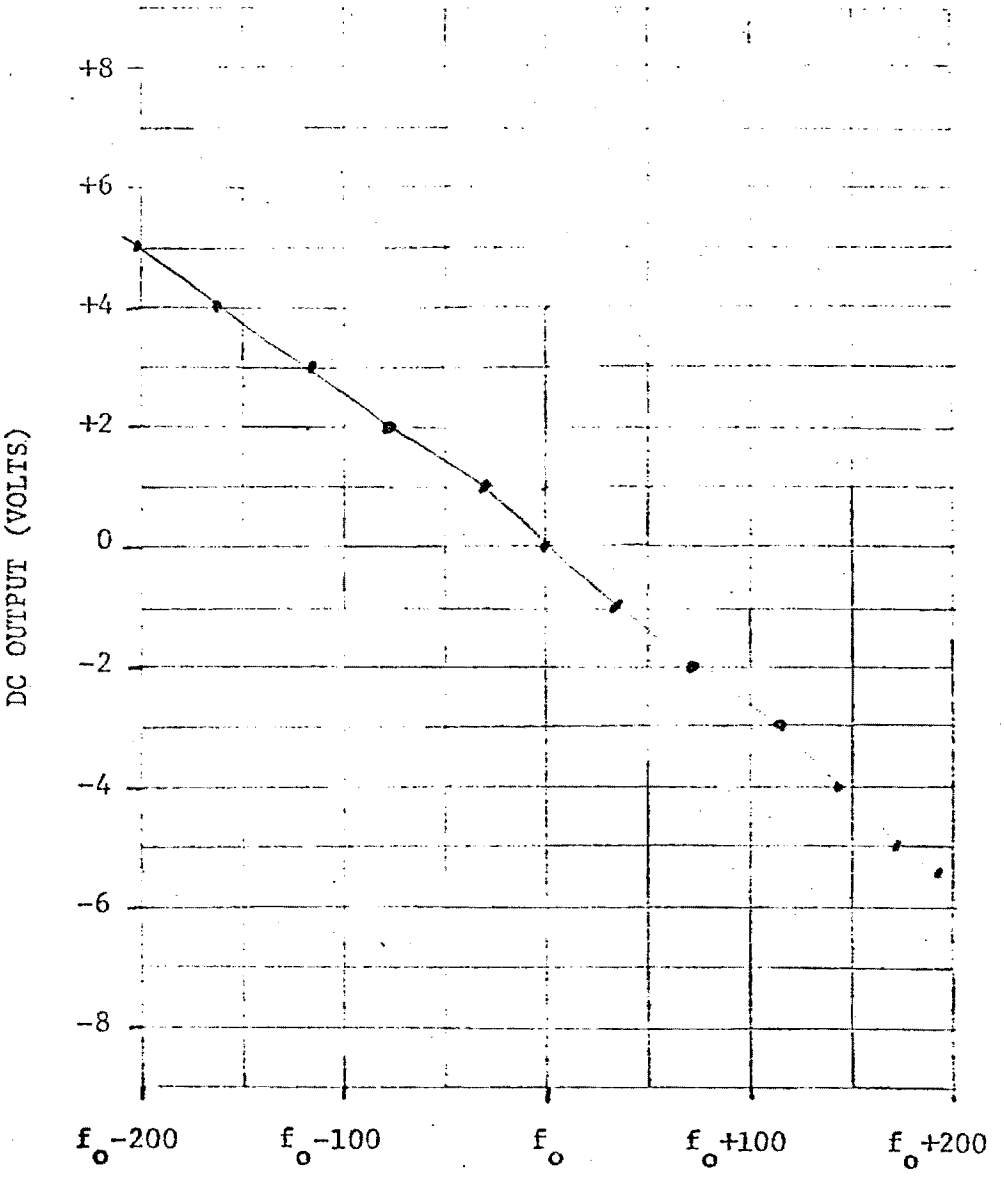
Tested by DPN
Signature

Date 8-30-76

TEST DATA

MODULES A1742-400 SERIAL NO. 002 MODIFIED

A1742-500 SERIAL NO. 002 "



f_o = 250.028 KHz

4.7 Discriminator Response

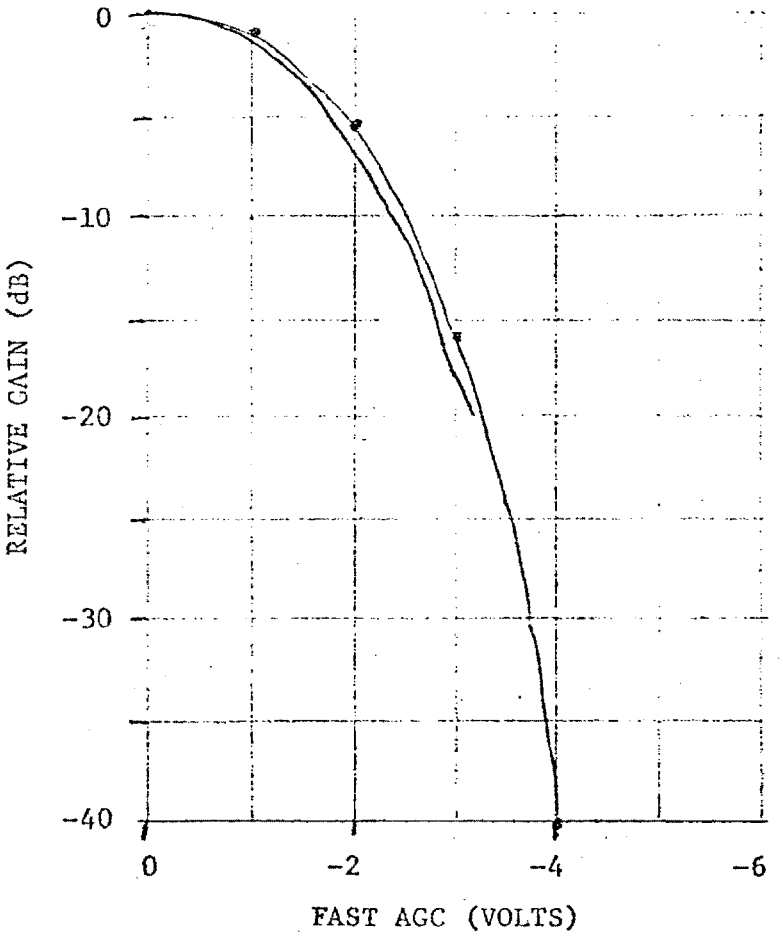
Tested by DPN
Signature

Dated 8-30-76

TEST DATA

MODULES A1742-400 SERIAL NO. 002 Modified

A1742-500 SERIAL NO. 002 "



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	_____V

TESTED BY DRV
SIGNATURE

DATE 8-30-76

TEST DATA

MODULES A1742-400 SERIAL NO. 002 (MODIFIED)

A1742-500 SERIAL NO. 002 "

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250,245 KHz
Bandpass Lower 3 dB Frequency	249.851 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	394 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.048 KHz

Tested by DPN
Signature

Date 8-30-76

TEST DATA

MODULE A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002

TEST	RESULT	LIMITS
6.1 DC Resistance (-600 Module)		
Pins A1-2	9.5 Ohms	5-15 Ohms
A1-GND	100 Ohms	100-120 Ohms
A2-3	9.9 Ohms	5-15 Ohms
A2-GND	100 Ohms	100-120 Ohms
2-GND	100 Ohms	90-110 Ohms
3-GND	90 Ohms	90-110 Ohms
6.2 Signal Output Level	✓ Check	1 Vpp Max
6.3 Bandpass Marker 2	10.25 MHz	
6.4 Bandpass Marker 1	9.75 MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	500 KHz	485-585 KHz
6.6 Bandpass Center Frequency		
$\sqrt{(\text{Marker 2})(\text{Marker 1})}$	10.00 MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0 dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)		
-600	1X Check	1X A7 Output
-700	4.5X Check	7X A7 Output
6.9 Spurious Responses		
-600	✓ Check	
-700	✓ Check	

Tested by _____
Signature

Date 8-30-76

TEST DATA

MODULES A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002

TEST	RESULT	LIMITS
6.10 Overall Gain	7.5 dB	~~8-12~~ dB 6-10 dB
6.11 Gain Reduction		
Slow AGC = -1.0 V	-3.9 dB	
-2.0 V	-11.6 dB	
-3.0 V	-27.2 dB	
-3.5 V	-35.1 dB	
6.12 AGC Symmetry	✓ Check	

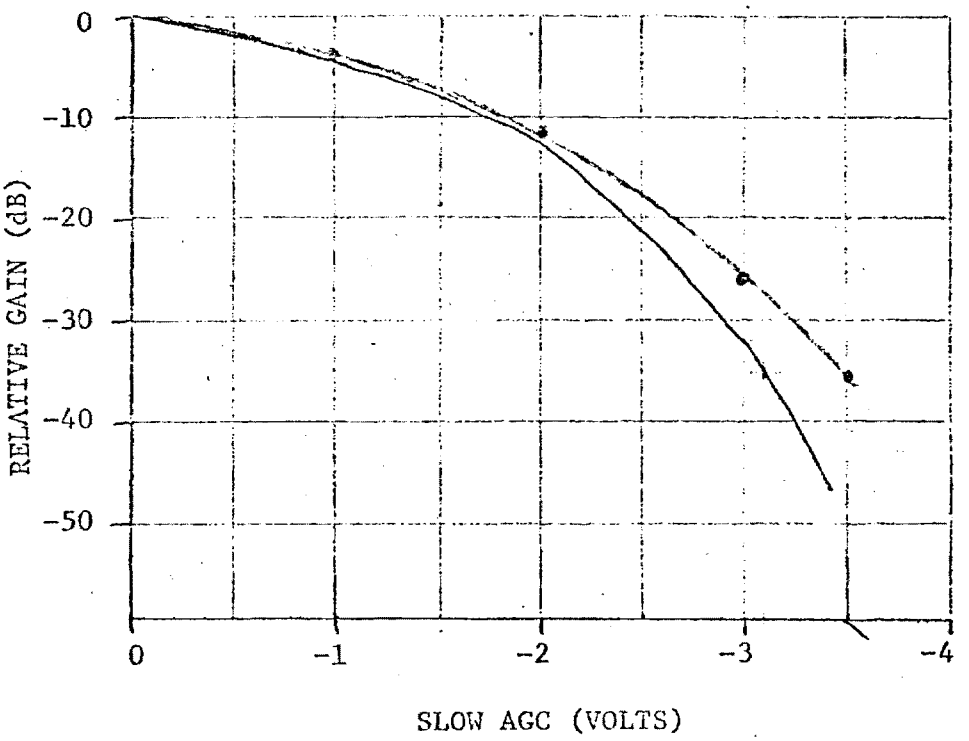
Tested by DPN
Signature

Date 8-30-76

TEST DATA

MODULES A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
6.13 SLOW AGC	0.4 V

TESTED BY DPN
SIGNATURE

DATE 8-30-76

TEST DATA

MODULES A1742-600 SERIAL NO. 002

A1742-700 SERIAL NO. 002

TEST	RESULT
6.14 Bandpass Response Slow AGC = -3V	
Bandpass Marker 2	10.23 MHz
Bandpass Marker 1	9.76 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	470 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99 MHz

Tested by DPN
Signature

Date 8-30-76

TEST DATA

MODULE A1742-800 SERIAL NO. 002

VCXO SERIAL NO. 002

TEST	RESULT	
8.1 Output Voltage and Frequency	1 Vrms Nominal	(1.8 MHz @ 0V +40 KHz @ -10V -40 KHz @ +10V Nominal)
Tuning Voltage (V)	Output Voltage (V)	Frequency (MHz)
-10	0.88	1.843
-8	0.90	1.834
-6	0.91	1.826
-4	0.92	1.817
-2	0.93	1.809
0	0.94	1.800
+2	0.94	1.791
+4	0.94	1.782
+6	0.94	1.774
+8	0.92	1.765
+10	0.88	1.756

8.2 Output Waveform ✓ Check

OVEN WAS ON DURING TESTS

Tested by

Signature

Date 6-29-76

A-1742 Acceptance Test Report
Equipment set #3 (modified)

A-1742

TEST DATA

MODULE A1742-100 SERIAL NO. 003 MODIFIED DATA

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	8.200 MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.067 good ~~10.073~~ MHz	
1.5	Bandpass Marker 1 Frequency	9.948 good ~~9.949~~ MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	119 good ~~124~~ KHz	110-130 KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.81 good ~~1.814~~ MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	8.3% Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	55.5 good ~~48~~ dB	54-58 dB
1.13	Notch Upper 3 dB Frequency	10.00275 MHz	
1.14	Notch Lower 3 dB Frequency	9.99701 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	5.74 KHz	4.5 - 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.800 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	>60 dB	40 dB min
1.18	AGC Test Frequency (f signal - f_{LO})	1.815 MHz	

Tested by _____
Signature

Date 25 June 76

TEST DATA

MODULE A1742-100 SERIAL NO. 003

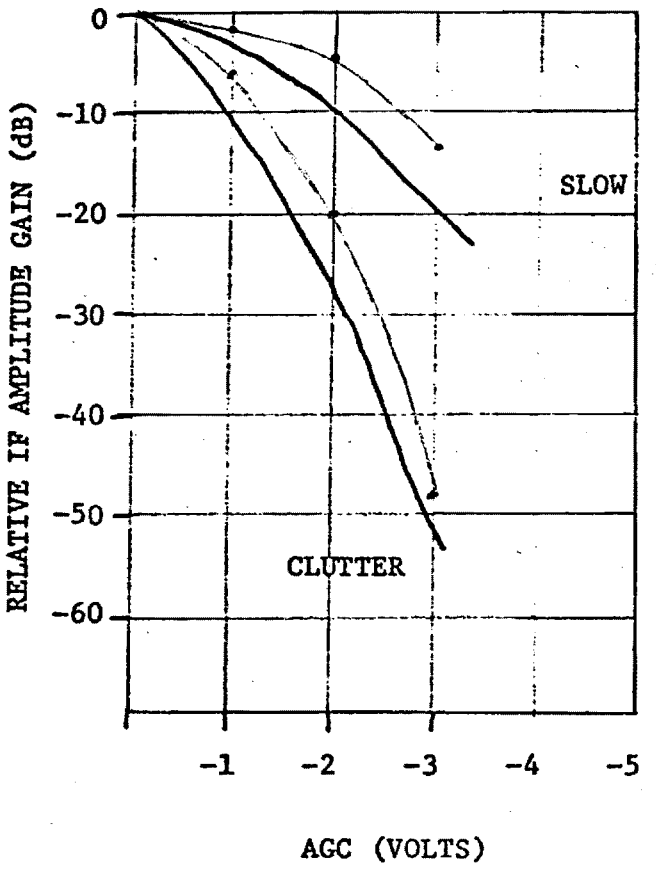
TEST		RESULT
1.19 Gain Reduction (Slow AGC = 0V)		
Clutter AGC =	-1.0 V	-6 dB
	-2.0 V	-20 dB
	-3.0 V	-48 dB
1.20 Gain Reduction (Clutter AGC = 0V)		
Slow AGC =	-1.0 V	-1.5 dB
=	-2.0 V	-4.7 dB
=	-3.0 V	-13 dB

Tested by _____
Signature

Date 25 June 76

TEST DATA

Module A1742-100 Serial No. 003



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.4 V
1.22 SLOW AGC	0.6 V

TESTED BY _____
SIGNATURE

DATE 25 June 76

TEST DATA

MODULE A1742-100 SERIAL NO. 003

TEST	RESULT
1.23 Bandpass Response	
Clutter AGC = -3V	
Slow AGC = -3V	
Local Oscillator Frequency	8.200 MHz
Bandpass Marker 2	10.069 MHz
Bandpass Marker 1	9.935 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	134 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.802 MHz

Tested by

Signature

Date 25 June 76

TEST DATA

MODULE A1742-200 SERIAL NO. 003

	TEST	RESULT		LIMITS
2.1	DC Resistance			
	Pins A1-2	9.5	Ohms	5-15 Ohms
	A1-GND	100	Ohms	100-120 Ohms
	A2-3	9.5	Ohms	5-15 Ohms
	A2-GND	100	Ohms	100-120 Ohms
	2-GND	95	Ohms	90-110 Ohms
	3-GND	95	Ohms	90-110 Ohms
2.2	Signal Output Level	✓	Check	1 Vpp Max
2.3	Bandpass Marker 2	10.219	MHz	
2.4	Bandpass Marker 1	9.522	MHz	
2.5	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	697	KHz	595-735 KHz
2.6	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.86	MHz	9.7 - 10.0 MHz
2.7	Dip at Center of Response Curve	0.4	dB	2 dB Max
2.8	Monitor Output (Percent of Signal Output)	✓	Check	100% nominal
2.9	Spurious Responses	✓	Check	
2.10	Overall Gain	30.5	dB	28-32 dB

Tested by _____
Signature

Date 6/12/76

TEST DATA

MODULE A1742-200 SERIAL NO. 003

	TEST	RESULT
2.11	Bandpass Response, Gain Pot set for Max Gain	
	Bandpass Marker 2	10.221 MHz
	Bandpass Marker 1	9.517 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	704 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.86 MHz
2.12	Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
	Bandpass Marker 2	10.214 MHz
	Bandpass Marker 1	9.548 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	666 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.875 MHz

Tested by _____
Signature

Date 6/12/76

TEST DATA

MODULE A1742-300 SERIAL NO. 003

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.8 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	✓ Check	2.8 Vpp Nominal
3.3	Signal Output Level	✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.318 MHz	
3.5	Frequency Marker 1	9.728 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	590 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})\quad(\text{Marker 1})} - f_{LO}$	8.218 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.2 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	✓ 8% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	~~41.5~~ 40.5 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	6.5 Vpp	
	Input Voltage	~~210~~ 185 mVpp	

Tested by _____
Signature

Date 6/12/76

TEST DATA

MODULES A1742-400 SERIAL NO. [illegible]

A1742-500 SERIAL NO. 003

	TEST	RESULT	LIMITS
4.1	Output Signal Level	✓ Check	8 V_{rms} Nominal
4.2	Bandpass Upper 3 dB Frequency	250.295 ~~250.278~~ KHz	
4.3	Bandpass Lower 3 dB Frequency	249.846 ~~249.802~~ KHz	
4.4	Bandpass Bandwidth ($f_{Up} - f_{LO}$)	449 ~~476~~ Hz	400-500 Hz
4.5	Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	250.040 KHz	250 KHz ± 200 Hz
4.6	Discriminator Response		
	DC Output = 0 V	250.040 KHz	250 KHz ± 200 Hz
	+1 V	249. 993 KHz	
	+2 V	249. 947 KHz	
	+3 V	249. 911 KHz	
	+4 V	249. 872 KHz	
	+5 V	249. 830 KHz	
	Positive Peak		
	5.0 V	249. 830 KHz	
	-1 V	250. 089 KHz	
	-2 V	250. 133 KHz	
	-3 V	250. 175 KHz	
	-4 V	250. 204 KHz	
	-5 V	250. 233 KHz	

Tested by _____

Signature

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003

TEST	RESULTS	LIMITS
Negative Peak		
-4.95 V	250.233 KHz	
4.7 See Discriminator Data Plot.		
4.8 Monitor Outputs (Percent of Signal Output)		
-400 pin A5	≈ 7% ✓ Check	15% Nominal
-500 pin A4	10% ✓ Check	10% Nominal
-500 pin A5	100% ✓ Check	100% Nominal
4.9 Gain Reduction		
Fast AGC = -1.0 V	-1.2 dB	
-2.0 V	-4.7 dB	
-3.0 V	-13.5 dB	
-4.0 V	-38 dB	
4.10 See AGC data plot.		
4.11 Local Oscillator		
Frequency	1.550 MHz	1.5-1.6 MHz
Level	12 Vpp ✓ Check	12 Vpp Nominal

Tested by _____ Signature

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003

TEST		RESULT	LIMITS
4.12	No Data Required		
4.13	Spurious Responses	✓ Check	
4.14	Overall Gain	74 73 dB	70-76 dB

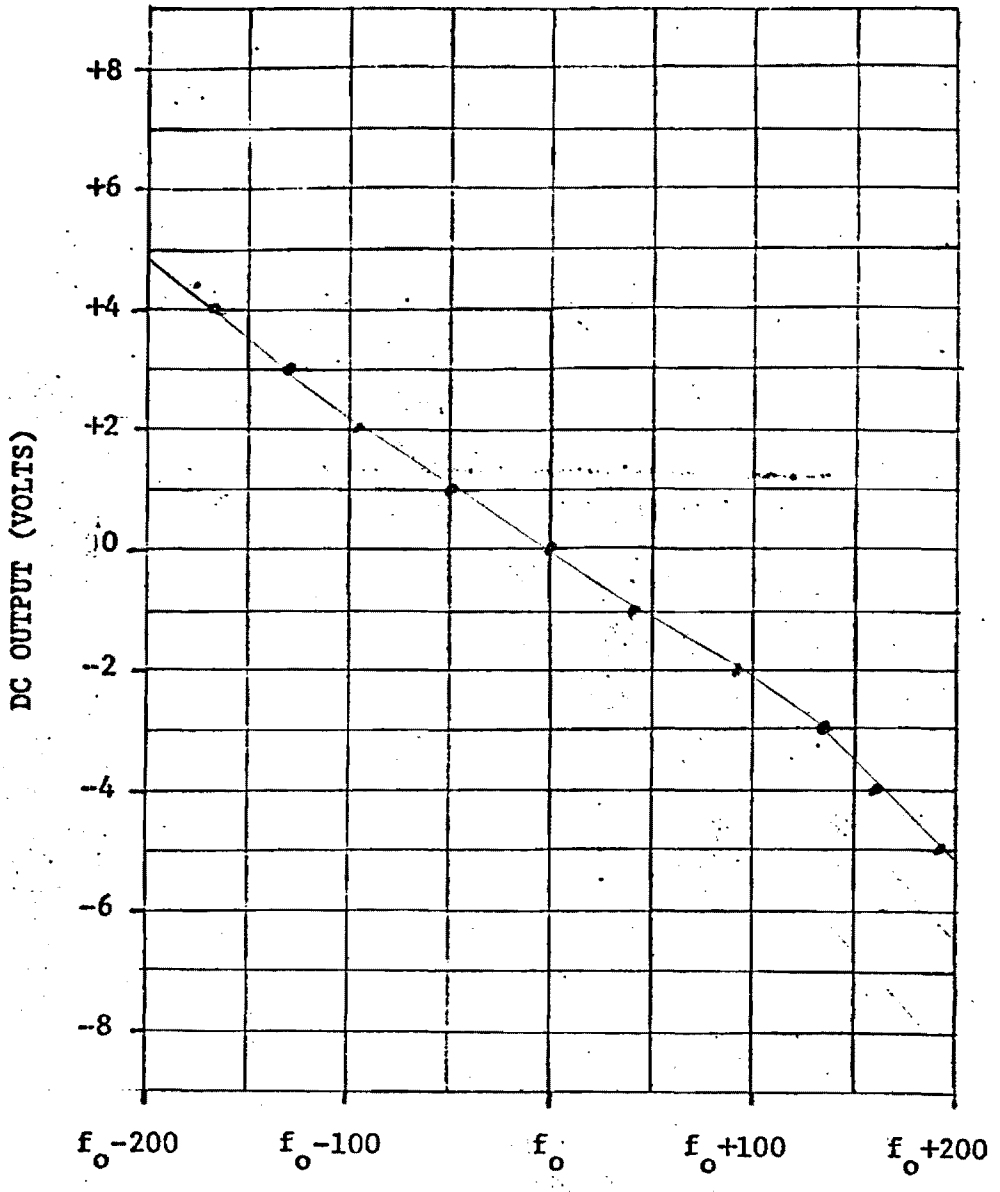
Tested by _____
Signature

Date _____

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003



f_o = 240.040 KHz

4.7 Discriminator Response

Tested by

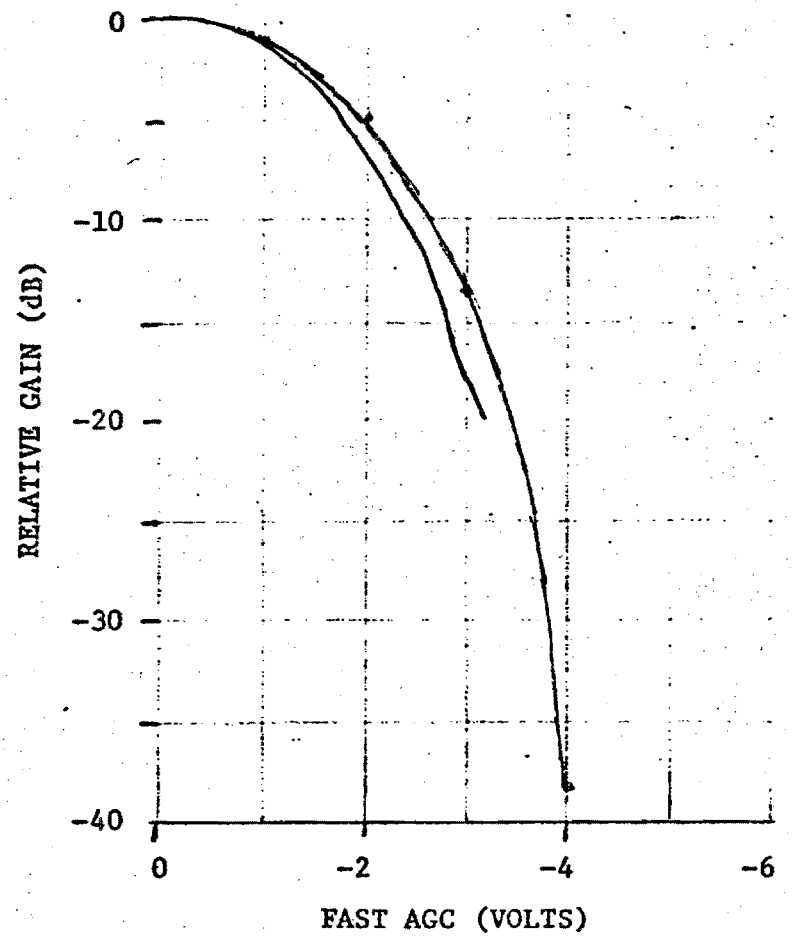
Signature

Dated 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	0.2 V

TESTED B

SIGNATURE

DATE 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250.283 KHz
Bandpass Lower 3 dB Frequency	249.791 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	492 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.037 KHz

Tested by _____
Signature

Date 28 June 76

TEST DATA

MODULE A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003

TEST	RESULT	LIMITS
6.1 DC Resistance (-600 Module)		
Pins A1-2	9.4 Ohms	5-15 Ohms
A1-GND	100 Ohms	100-120 Ohms
A2-3	9.3 Ohms	5-15 Ohms
A2-GND	100 Ohms	100-120 Ohms
2-GND	95 Ohms	90-110 Ohms
3-GND	95 Ohms	90-110 Ohms
6.2 Signal Output Level	✓ Check	1 Vpp Max
6.3 Bandpass Marker 2	10,293 MHz	
6.4 Bandpass Marker 1	9.731 MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	562 KHz	485-585 KHz
6.6 Bandpass Center Frequency		
$\sqrt{(\text{Marker 2})(\text{Marker 1})}$	10.008 MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0.1 dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)		
-600	✓ Check	1X Nominal
-700	4.4X Check	7X Nominal
6.9 Spurious Responses		
-600	✓ Check	
-700	✓ Check	

Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULES A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003

TEST		RESULT	LIMITS
6.10 Overall Gain		~~10~~ 8.0 dB	8-12 dB
6.11 Gain Reduction			
	Slow AGC = -1.0 V	-3 dB	
	-2.0 V	-11 dB	
	-3.0 V	-20 dB	
	-3.5 V	-24 dB	
6.12 AGC Symmetry		V Check	

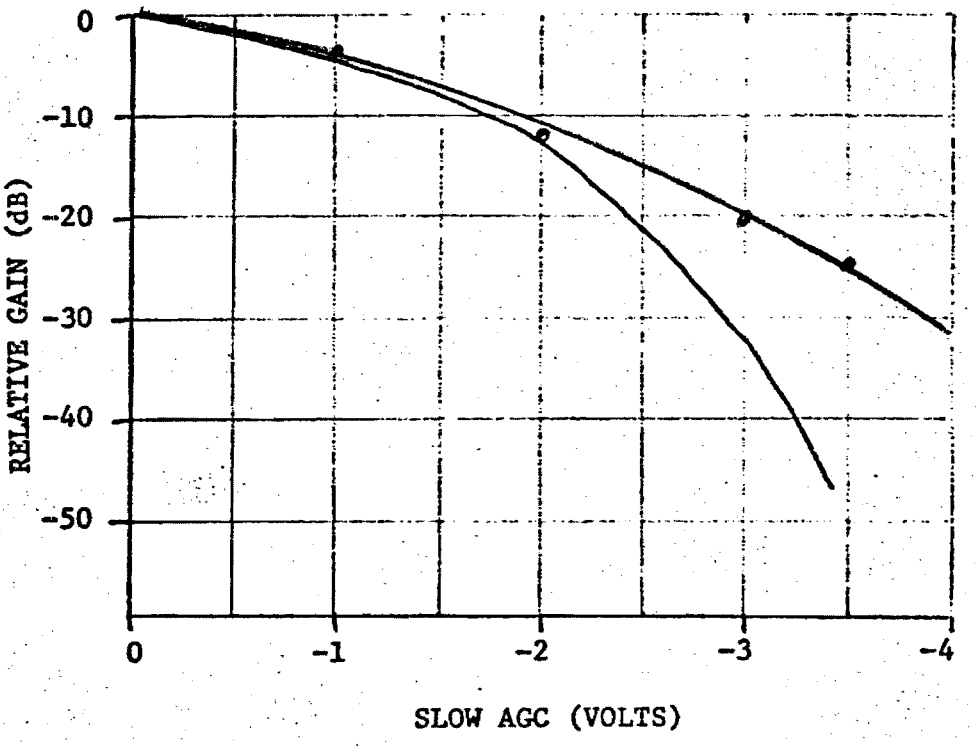
Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULES A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
6.13 SLOW AGC	1.1 v @-30db

TESTED BY _____
SIGNATURE

DATE 6/11/76

TEST DATA

MODULES A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003

TEST	RESULT
6.14 Bandpass Response Slow AGC = -3V	
Bandpass Marker 2	10.267 MHz
Bandpass Marker 1	9.822 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	445 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	10.042 MHz

Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULE A1742-800 SERIAL NO. 003

VCXO SERIAL NO. 3

TEST	RESULT	
8.1 Output Voltage and Frequency	1 Vrms Nominal	(1.8 MHz @ 0V +40 KHz @ -10V -40 KHz @ +10V Nominal)
Tuning Voltage (V)	Output Voltage (V)	Frequency (MHz)
-10	0.85	1.843
-8	0.86	1.835
-6	0.87	1.826
-4	0.88	1.818
-2	0.88	1.809
0	0.89	1.800
+2	0.89	1.791
+4	0.88	1.782
+6	0.88	1.773
+8	0.87	1.764
+10	0.85	1.755
8.2 Output Waveform	✓ Check	

OVEN WAS ON DURING TESTS.

Tested by

Signature

Date 6-29-76

Acceptance Test Report 3

TEST DATA

MODULE A1742-100 SERIAL NO. 003

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	8.200 MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.0732 MHz	
1.5	Bandpass Marker 1 Frequency	9.949 MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	124 KHz	110-130 KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.811 MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	83% ✓ Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	48 dB	48-52 dB
1.13	Notch Upper 3 dB Frequency	10.00275 MHz	
1.14	Notch Lower 3 dB Frequency	9.997101 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	5.74 KHz	4.5 - 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.800 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	> 60 dB	40 dB min
1.18	AGC Test Frequency (f signal - f_{LO})	1.815 MHz	

Tested by _____

Signature

Date 25 June 76

TEST DATA

MODULE A1742-100 SERIAL NO. 003

TEST		RESULT
1.19 Gain Reduction (Slow AGC = 0V)		
Clutter AGC =	-1.0 V	-6 dB
	-2.0 V	-20 dB
	-3.0 V	-48 dB
1.20 Gain Reduction (Clutter AGC = 0V)		
Slow AGC =	-1.0 V	-1.5 dB
=	-2.0 V	-4.7 dB
=	-3.0 V	-13 dB

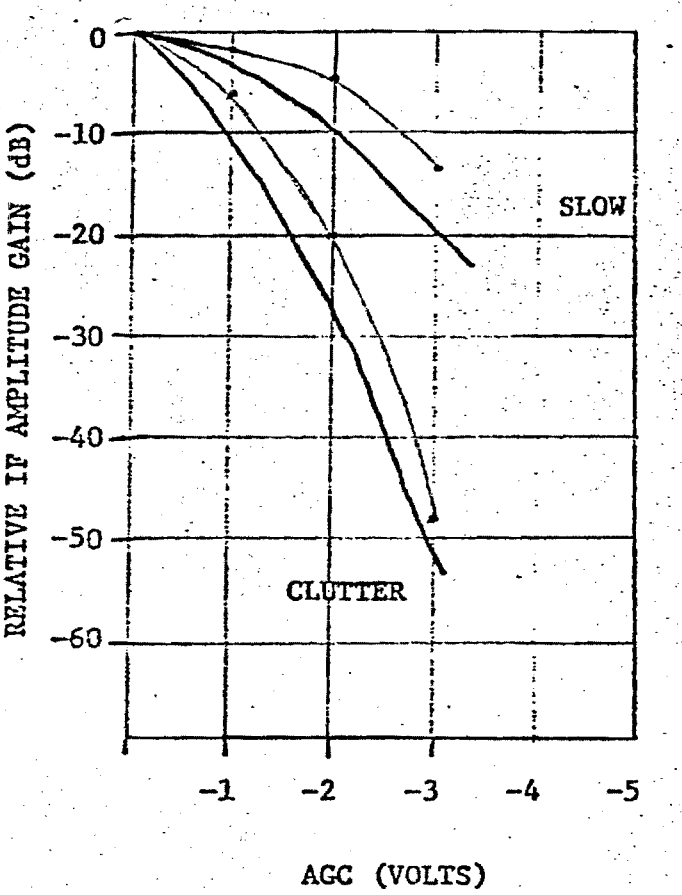
Tested by

Signature

Date 25 June 76

TEST DATA

Module A1742-100 Serial No. 003



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.4 V
1.22 SLOW AGC	0.6 V

TESTED BY

SIGNATURE

DATE 25 June 76

TEST DATA

MODULE A1742-100 SERIAL NO. 003

TEST	RESULT
1.23 Bandpass Response	
Clutter AGC = -3V	
Slow AGC = -3V	
Local Oscillator Frequency	8.200 MHz
Bandpass Marker 2	10.069 MHz
Bandpass Marker 1	9.935 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	134 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.802 MHz

Tested by _____
Signature

Date 25 June 76

TEST DATA

MODULE A1742-200 SERIAL NO. 003

TEST	RESULT	LIMITS
2.1 DC Resistance		
Pins A1-2	9.5 Ohms	5-15 Ohms
A1-GND	100 Ohms	100-120 Ohms
A2-3	9.5 Ohms	5-15 Ohms
A2-GND	100 Ohms	100-120 Ohms
2-GND	95 Ohms	90-110 Ohms
3-GND	95 Ohms	90-110 Ohms
2.2 Signal Output Level	✓ Check	1 Vpp Max
2.3 Bandpass Marker 2	10.219 MHz	
2.4 Bandpass Marker 1	9.522 MHz	
2.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	697 KHz	595-735 KHz
2.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.86 MHz	9.7 - 10.0 MHz
2.7 Dip at Center of Response Curve	0.4 dB	2 dB Max
2.8 Monitor Output (Percent of Signal Output)	✓ Check	100% nominal
2.9 Spurious Responses	✓ Check	
2.10 Overall Gain	30.5 dB	28-32 dB

Tested by _____

Signature

Date 6/12/76

TEST DATA

MODULE A1742-200 SERIAL NO. 003

TEST		RESULT
2.11	Bandpass Response, Gain Pot set for Max Gain	
	Bandpass Marker 2	10.221 MHz
	Bandpass Marker 1	9.517 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	704 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.86 MHz
2.12	Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
	Bandpass Marker 2	10.214 MHz
	Bandpass Marker 1	9.548 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	666 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.875 MHz

Tested by _____
Signature

Date 6/12/74

TEST DATA

MODULE A1742-300 SERIAL NO. 003

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.8 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	✓ Check	2.8 Vpp Nominal
3.3	Signal Output Level	✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.318 MHz	
3.5	Frequency Marker 1	9.728 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	590 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})\ (\text{Marker 1})} - f_{LO}$	8.218 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.2 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	✓ 8% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	41.5 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	6.5 Vpp	
	Input Voltage	210 mVpp	

Tested by _____
Signature

Date 6/12/76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003

TEST		RESULT	LIMITS
4.1	Output Signal Level	✓ Check	8 V_{rms} Nominal
4.2	Bandpass Upper 3 dB Frequency	250.278 KHz	
4.3	Bandpass Lower 3 dB Frequency	249,802 KHz	
4.4	Bandpass Bandwidth ($f_{Up} - f_{LO}$)	476 Hz	400-500 Hz
4.5	Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	250.040 KHz	250 KHz ± 200 Hz
4.6	Discriminator Response		
	DC Output = 0 V	240.040 KHz	250 KHz ± 200 Hz
	+1 V	249.993 KHz	
	+2 V	249.947 KHz	
	+3 V	249.911 KHz	
	+4 V	249.872 KHz	
	+5 V	249.830 KHz	
	Positive Peak		
	5.0 V	249.830 KHz	
	-1 V	250.089 KHz	
	-2 V	250.133 KHz	
	-3 V	250.175 KHz	
	-4 V	250.204 KHz	
	~~-4.95 -5 V~~	250.233 KHz	

Tested by

Signature ✓

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003

TEST	RESULTS	LIMITS
Negative Peak		
-4.95 V	250.233 KHz	
4.7 See Discriminator Data Plot.		
4.8 Monitor Outputs (Percent of Signal Output)		
-400 pin A5	≈ 7% ✓ Check	15% Nominal
-500 pin A4	10% ✓ Check	10% Nominal
-500 pin A5	100% ✓ Check	100% Nominal
4.9 Gain Reduction		
Fast AGC = -1.0 V	-1.2 dB	
-2.0 V	-4.7 dB	
-3.0 V	-13.5 dB	
-4.0 V	-38 dB	
4.10 See AGC data plot.		
4.11 Local Oscillator		
Frequency	1.550 MHz	1.5-1.6 MHz
Level	12½0 ✓ Check	12 Vpp Nominal

Tested by _____
Signature

Date 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 603

A1742-500 SERIAL NO. 003

TEST	RESULT	LIMITS
4.12 No Data Required		
4.13 Spurious Responses	✓ Check	
4.14 Overall Gain	73 dB	70-76 dB

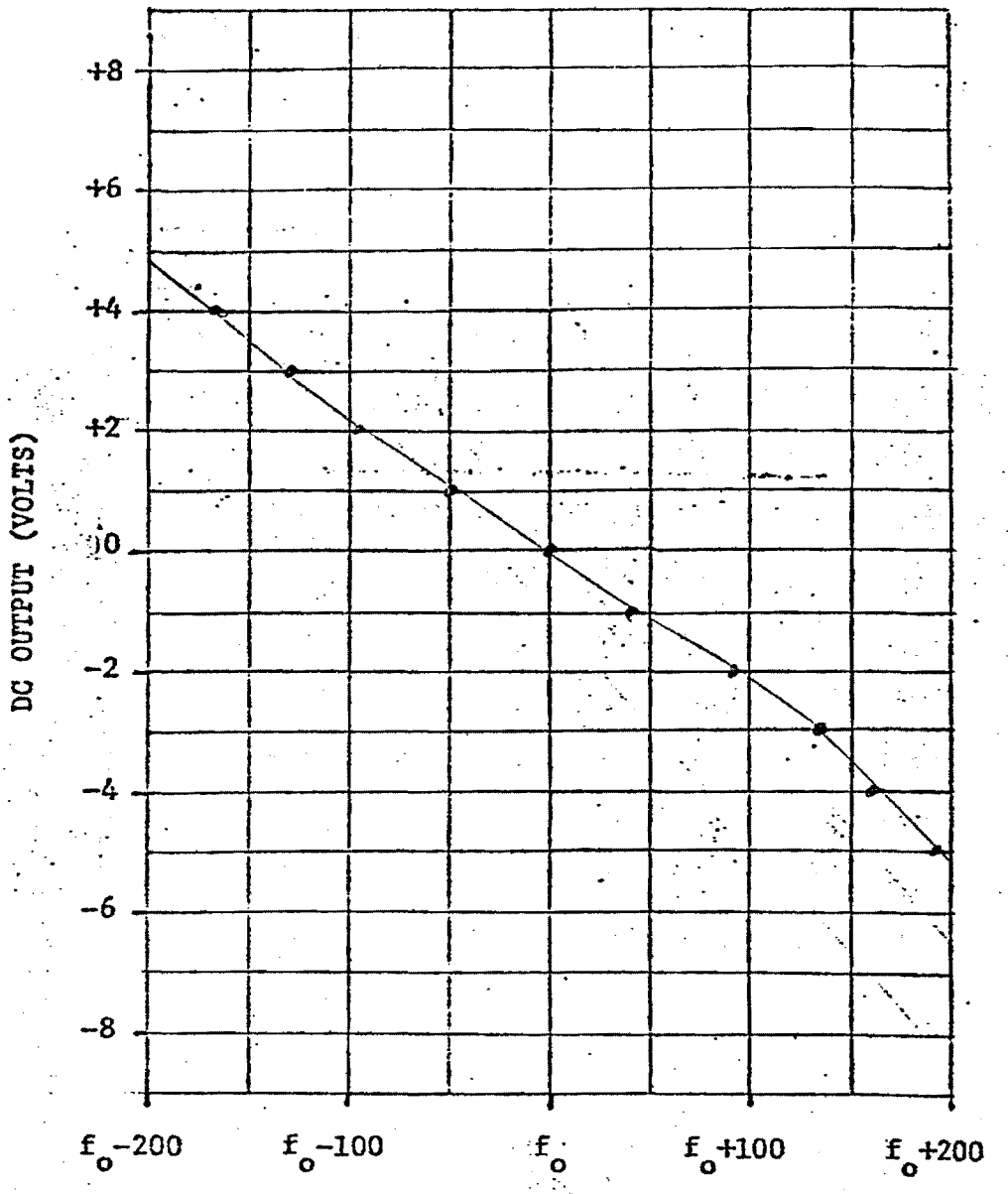
Tested by

Signature

Date 28 June 76

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003



f_o = 240.040 KHz

4.7 Discriminator Response

Tested by

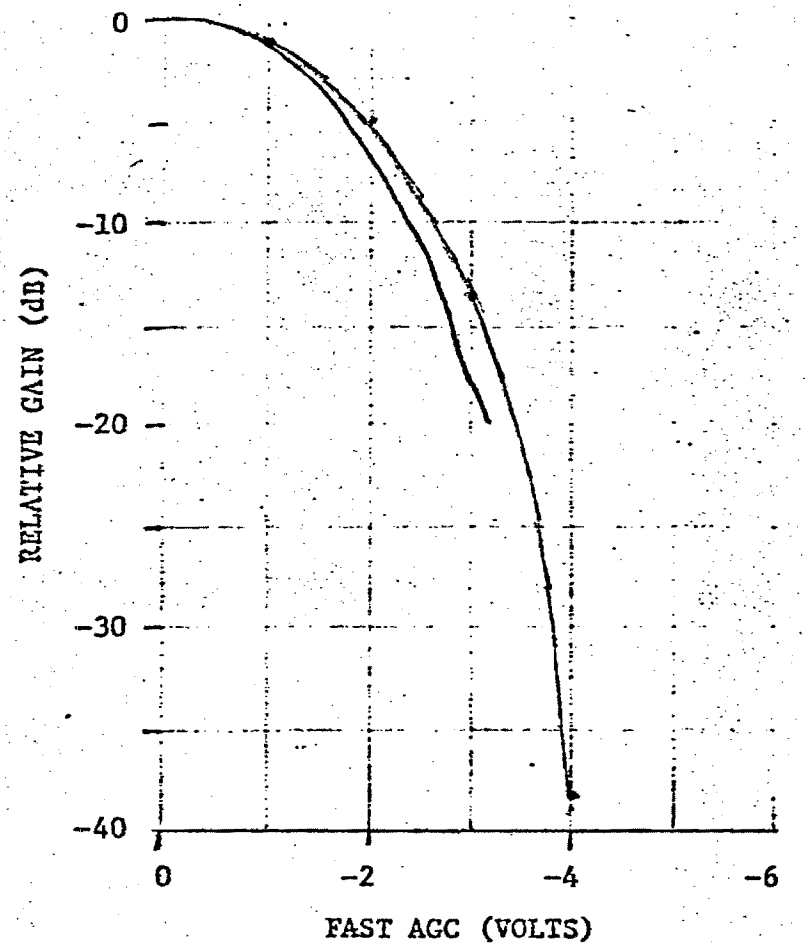
Signature

Dated 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	0.2 V

TESTED BY

SIGNATURE

DATE 28 June 76

TEST DATA

MODULES A1742-400 SERIAL NO. 003

A1742-500 SERIAL NO. 003

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250.283 KHz
Bandpass Lower 3 dB Frequency	249.791 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	492 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.037 KHz

Tested by

Signature

Date 28 June 76

TEST DATA

MODULE A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003

TEST	RESULT	LIMITS
6.1 DC Resistance (-600 Module)		
Pins A1-2	9.4 Ohms	5-15 Ohms
A1-GND	102 Ohms	100-120 Ohms
A2-3	9.3 Ohms	5-15 Ohms
A2-GND	100 Ohms	100-120 Ohms
2-GND	95 Ohms	90-110 Ohms
3-GND	95 Ohms	90-110 Ohms
6.2 Signal Output Level	✓ Check	1 Vpp Max
6.3 Bandpass Marker 2	10.293 MHz	
6.4 Bandpass Marker 1	9.731 MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	562 KHz	485-585 KHz
6.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	10.008 MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0.1 dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)		
-600	✓ Check	1X Nominal
-700	4.4X Check	7X Nominal
6.9 Spurious Responses		
-600	✓ Check	
-700	✓ Check	

Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULES A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003

TEST		RESULT	LIMITS
6.10 Overall Gain		10 dB	8-12 dB
6.11 Gain Reduction			
Slow AGC =	-1.0 V	-3 dB	
	-2.0 V	-11 dB	
	-3.0 V	-20 dB	
	-3.5 V	-24 dB	
6.12 AGC Symmetry		V Check	

Tested by _____
Signature

Date 6/11/76

TEST DATA

MODULES A1742-600 SERIAL NO. 003

A1742-700 SERIAL NO. 003

TEST	RESULT
6.14 Bandpass Response Slow AGC = -3V	
Bandpass Marker 2	10.267 MHz
Bandpass Marker 1	9.822 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	445 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	10.042 MHz

Tested by _____

Signature

Date 6/11/76

TEST DATA

MODULE A1742-800 SERIAL NO. 003

VCXO SERIAL NO. 3

TEST	RESULT	
8.1 Output Voltage and Frequency	1 Vrms Nominal	(1.8 MHz @ 0V +40 KHz @ -10V -40 KHz @ +10V Nominal)

Tuning Voltage (V)	Output Voltage (V)	Frequency (MHz)
-10	0.85	1.843
-8	0.86	1.835
-6	0.87	1.826
-4	0.88	1.818
-2	0.88	1.809
0	0.89	1.800
+2	0.89	1.791
+4	0.88	1.782
+6	0.88	1.773
+8	0.87	1.764
+10	0.85	1.755

8.2 Output Waveform ✓ Check

OVEN WAS ON DURING TESTS.

Tested by

Signature

Date 6-29-76

A-1742

Acceptance Test Report (DATA) Fourth Equipment set

A-1742

TEST DATA

MODULE A1742-100 SERIAL NO. 004

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	8.200 MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.077 MHz	
1.5	Bandpass Marker 1 Frequency	9.949 MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	128 KHz	110-130 KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.813 MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	9.3% Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	55 dB	54-58 dB
1.13	Notch Upper 3 dB Frequency	10.00217 MHz	
1.14	Notch Lower 3 dB Frequency	9.9972 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	4.97 KHz	4.5 - 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.800 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	>60 dB	40 dB min
1.18	AGC Test Frequency (f signal - f_{LO})	1.815 MHz	

Tested by _____

Signature

Date 18 September 1976

TEST DATA

MODULE A1742-100 SERIAL NO. 004

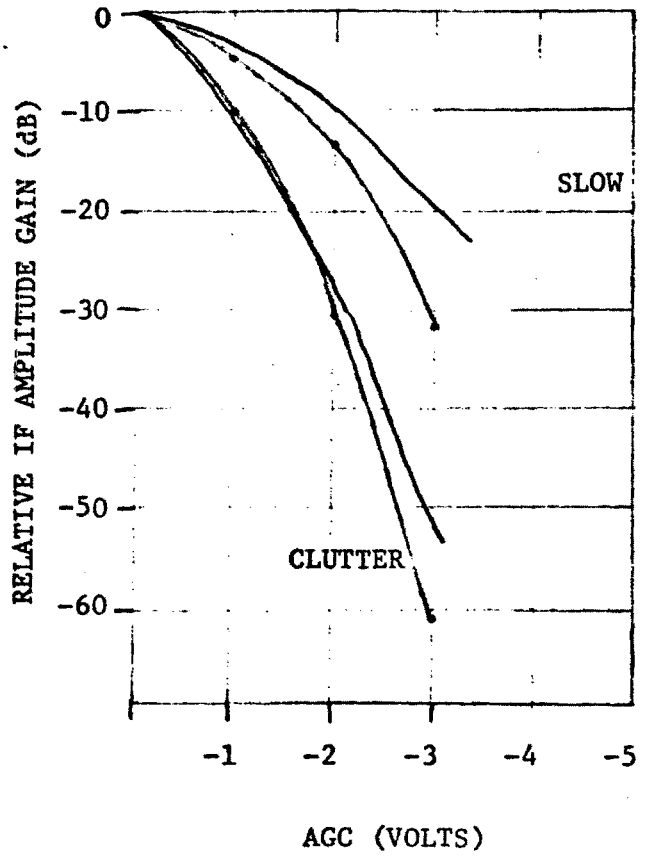
TEST		RESULT
1.19 Gain Reduction (Slow AGC = 0V)		
Clutter AGC =	-1.0 V	-10 dB
	-2.0 V	-30.5 dB
	-3.0 V	-61 dB
1.20 Gain Reduction (Clutter AGC = 0V)		
Slow AGC =	-1.0 V	-4.8 dB
=	-2.0 V	-13.5 dB
=	-3.0 V	-31.8 dB

Tested by _____
Signature

Date 8 Sept 76

TEST DATA

Module A1742-100 Serial No. 004



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.3 V
1.22 SLOW AGC	0.6 V

TESTED BY _____
SIGNATURE

DATE 8 Sept 76

TEST DATA

MODULE A1742-100 SERIAL NO. 004

TEST	RESULT
1.23 Bandpass Response	
Clutter AGC = -3V (-2.5V)	
Slow AGC = -3V (-2.5V)	
Local Oscillator Frequency	8.200 MHz
Bandpass Marker 2	10.105 MHz
Bandpass Marker 1	9.95 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	155 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.827 MHz

Tested by _____
Signature

Date 8 Sept 76

TEST DATA

MODULE A1742-200 SERIAL NO. 004

TEST	RESULT	LIMITS
2.1 DC Resistance		
Pins A1-2	10 Ohms	5-15 Ohms
A1-GND	110 Ohms	100-120 Ohms
A2-3	10 Ohms	5-15 Ohms
A2-GND	110 Ohms	100-120 Ohms
2-GND	100 Ohms	90-110 Ohms
3-GND	100 Ohms	90-110 Ohms
2.2 Signal Output Level	✓ Check	1 Vpp Max
2.3 Bandpass Marker 2	10.215 MHz	
2.4 Bandpass Marker 1	9.482 MHz	
2.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	733 KHz	595-735 KHz
2.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.842 MHz	9.7 - 10.0 MHz
2.7 Dip at Center of Response Curve	0 dB	2 dB Max
2.8 Monitor Output (Percent of Signal Output)	100% Check	100% nominal
2.9 Spurious Responses	✓ Check	
2.10 Overall Gain	33 dB	28-32 dB

Tested by _____
Signature

Date _____

TEST DATA

MODULE A1742-200 SERIAL NO. 004

	TEST	RESULT
2.11	Bandpass Response, Gain Pot set for Max Gain	
	Bandpass Marker 2	10.187 MHz
	Bandpass Marker 1	9.468 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	719 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.821 MHz
2.12	Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
	Bandpass Marker 2	10.236 MHz
	Bandpass Marker 1	9.509 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	727 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.866 MHz

Tested by _____
Signature

Date 8 Sept. 76

TEST DATA

MODULES A1742-400 SERIAL NO. 004

A1742-500 SERIAL NO. 004

	TEST	RESULT	LIMITS
4.1	Output Signal Level	✓ Check	8 V_{rms} Nominal
4.2	Bandpass Upper 3 dB Frequency	250.261 KHz	
4.3	Bandpass Lower 3 dB Frequency	249.792 KHz	
4.4	Bandpass Bandwidth $(f_{Up} - f_{LO})$	.469 Hz	400-500 Hz
4.5	Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	250.026 KHz	250 KHz ± 200 Hz
4.6	Discriminator Response		f_0
	DC Output = 0 V	250.028 KHz	~~250~~ KHz ± 20 Hz
	+1 V	249.990 KHz	
	+2 V	249.956 KHz	
	+3 V	249.927 KHz	
	+4 V	249.902 KHz	
	+5 V	249.875 KHz	
	Positive Peak		
	+5.9 V	249.832 KHz	
	-1 V	250.067 KHz	
	-2 V	250.102 KHz	
	-3 V	250.132 KHz	
	-4 V	250.158 KHz	
	-5 V	250.187 KHz	

Tested by _____
Signature

Date 9 September 1976

TEST DATA

MODULES A1742-400 SERIAL NO. 004

A1742-500 SERIAL NO. 004

TEST	RESULTS	LIMITS
Negative Peak		
-6.4 V	250.230 KHz	

4.7 See Discriminator Data Plot.

4.8 Monitor Outputs (Percent of Signal Output)

-400 pin A5	13% Check	15% Nominal
-500 pin A4	10% Check	10% Nominal
-500 pin A5	100% Check	100% Nominal

4.9 Gain Reduction

Fast AGC = -1.0 V	-1.4 dB	
-2.0 V	-5.0 dB	
-3.0 V	-15.2 dB	
-4.0 V	-34.0 dB	

4.10 See AGC data plot.

4.11 Local Oscillator

Frequency	1.570 MHz	1.5-1.6 MHz
Level	✓ Check	12 Vpp Nominal

Tested by _____
Signature

Date 8 Sept 76

TEST DATA

MODULES A1742-400 SERIAL NO. 004

A1742-500 SERIAL NO. 004

	TEST	RESULT	LIMITS
4.12	No Data Required		
4.13	Spurious Responses	✓ Check	
4.14	Overall Gain	77.5 dB	70-76 dB

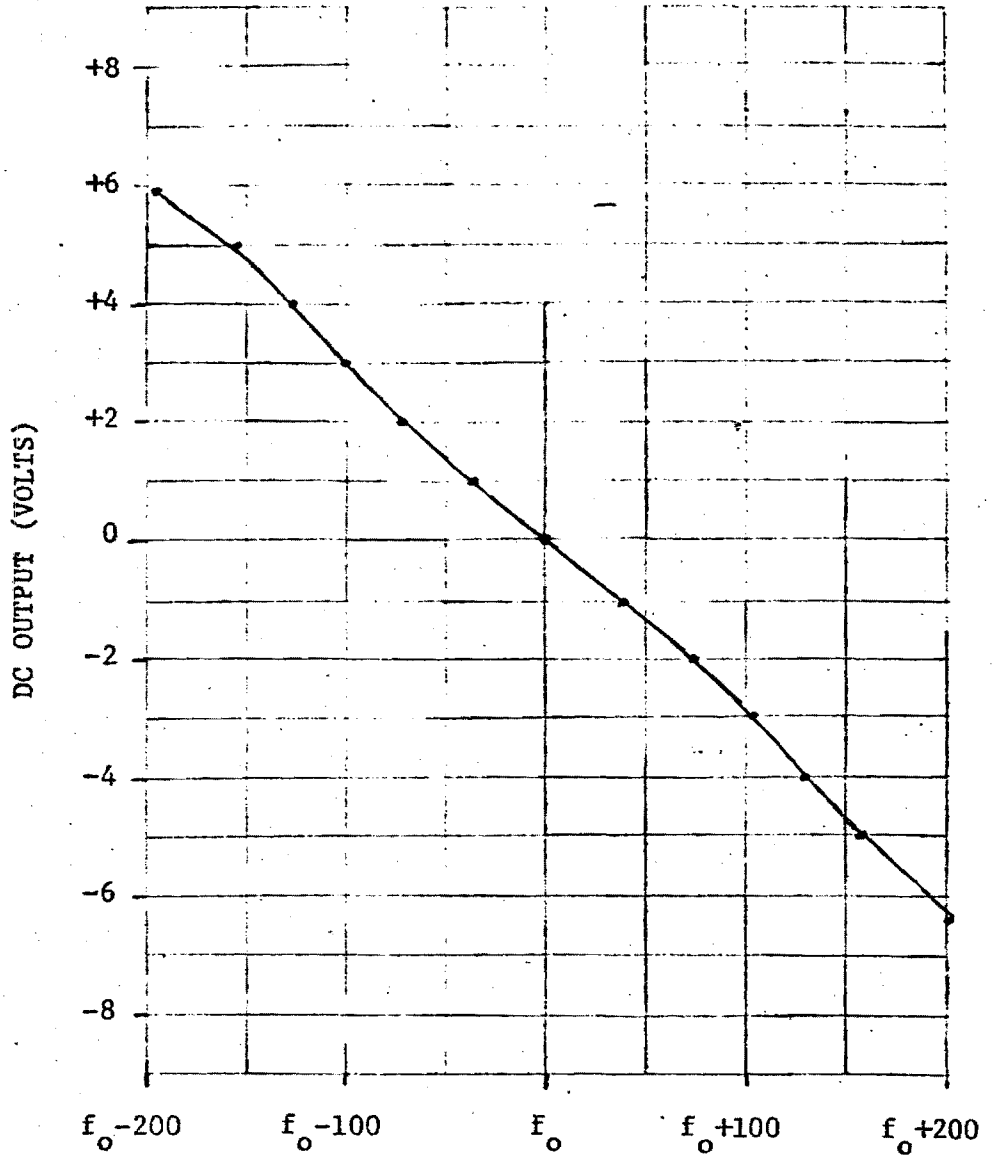
Tested by _____
Signature

Date 8 Sept 76

TEST DATA

MODULES A1742-400 SERIAL NO. 004

A1742-500 SERIAL NO. 004



f_o = 250.028KHz

4.7 Discriminator Response

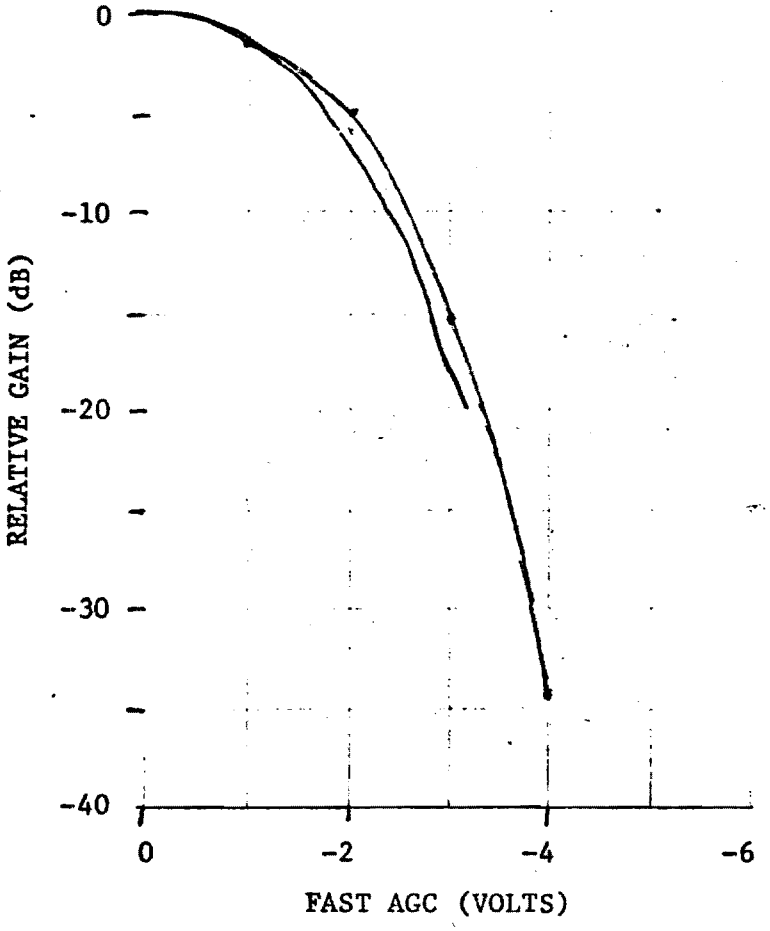
Tested by _____
Signature

Dated 9 Sept 76

TEST DATA

MODULES A1742-400 SERIAL NO. 004

A1742-500 SERIAL NO. 004



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	0.2 V

TESTED BY _____ _____
SIGNATURE

DATE 8 Sept 76

TEST DATA

MODULES A1742-400 SERIAL NO. 004

A1742-500 SERIAL NO. 004

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250.255 KHz
Bandpass Lower 3 dB Frequency	249.791 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	464 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.023 KHz

Tested by _____
Signature

Date 8 Sept 76

TEST DATA

MODULE A1742-600 SERIAL NO. 004

A1742-700 SERIAL NO. 004

TEST	RESULT		LIMITS
6.1 DC Resistance (-600 Module)			
Pins A1-2	9	Ohms	5-15 Ohms
A1-GND	109	Ohms	100-120 Ohms
A2-3	9	Ohms	5-15 Ohms
A2-GND	109	Ohms	100-120 Ohms
2-GND	100	Ohms	90-110 Ohms
3-GND	100	Ohms	90-110 Ohms
6.2 Signal Output Level	✓	Check	1 Vpp Max
6.3 Bandpass Marker 2	10.265	MHz	
6.4 Bandpass Marker 1	9.726	MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	539	KHz	485-585 KHz
6.6 Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99	MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0	dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)			
-600	0.95X	Check	1X A7 Output
-700	4X	Check	7X A7 Output
6.9 Spurious Responses			
-600	✓	Check	
-700	✓	Check	

Tested by [signature]

Signature

Date 9 September 76

TEST DATA

MODULES A1742-600 SERIAL NO. 004

A1742-700 SERIAL NO. 004

TEST		RESULT	LIMITS
6.10 Overall Gain		8.5 dB	6-10 dB
6.11 Gain Reduction			
	Slow AGC = -1.0 V	-3.0 dB	
	-2.0 V	-9.1 dB	
	-3.0 V	-21.4 dB	
	-3.5 V	-32.0 dB	
6.12 AGC Symmetry		✓ Check	

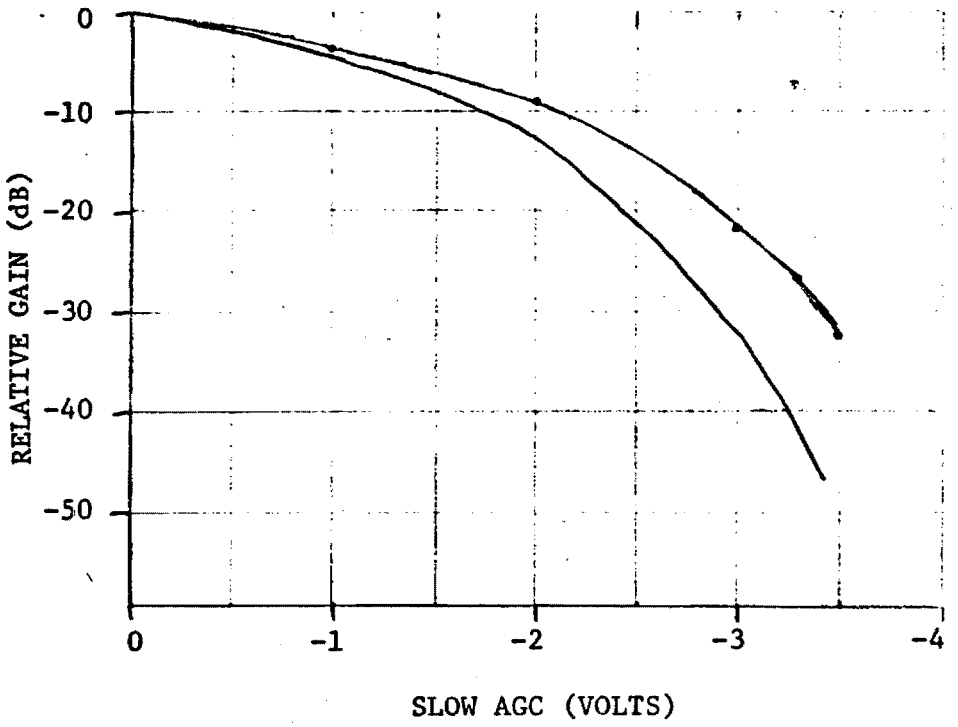
Tested by _____
Signature

Date 9 Sept 76

TEST DATA

MODULES A1742-600 SERIAL NO. 004

A1742-700 SERIAL NO. 004



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
6.13 SLOW AGC	0.5 V

TESTED BY _____
SIGNATURE

DATE 9 Sept 76

TEST DATA

MODULES A1742-600 SERIAL NO. 004

A1742-700 SERIAL NO. 004

TEST	RESULT
6.14 Bandpass Response Slow AGC = -3V	
Bandpass Marker 2	10.246 MHz
Bandpass Marker 1	9.741 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	505 KHz
Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99 MHz

Tested by _____
Signature

Date 9 Sept. 76

TEST DATA

MODULE A1742-800 SERIAL NO. 004 already tested

VCXO SERIAL NO. _____

TEST	RESULT	
8.1 Output Voltage and Frequency	1 Vrms Nominal	(1.8 MHz @ 0V +40 KHz @ -10V -40 KHz @ +10V Nominal)
Tuning Voltage (V)	Output Voltage (V)	Frequency (MHz)
-10	0.85	1.756
-8	0.88	1.765
-6	0.90	1.773
-4	0.90	1.782
-2	0.91	1.791
0	0.91	1.800
+2	0.90	1.809
+4	0.89	1.817
+6	0.88	1.826
+8	0.87	1.834
+10	0.86	1.843
8.2 Output Waveform	✓ Check	

Tested by _____

Signature

Date 7-16-76

TEST DATA

SYSTEM TESTS

A1742 SERIAL NO. 004

A. Background Noise:
(With AGCs grounded, measured at -500 Pin A5) .30 V P-P

B. Overall Signal Characteristics and Background Noise
(50Ω Gen)

Clutter AGC	1.6	Volts
Gain Suppression	20	dB
Background Noise	≈4	V P-P

(Measured at -500 Pin A5)

Input Level vs. Output at Monitor Ports

Input Signal = -45 dBm @ -600 Pin A1 & A2

Monitor Ports Output @ -600 A5	0.44	V P-P
-700 A5	0.5	V P-P

Input Level = -63 dBm

-100 A5	0.2	V P-P

Input Level = -111 dBm

-400 A5	0.4	V P-P
-500 A4	4.0	V P-P
-500 A5	40	V P-P

9 September 1976

TEST DATA

MODULE A1742-300 SERIAL NO. 005

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.800 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	✓ Check	2.8 Vpp Nominal
3.3	Signal Output Level	✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.307 MHz	
3.5	Frequency Marker 1	9.718 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	589 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})\quad(\text{Marker 1})} - f_{LO}$	8.208 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.6 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	8.8% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	40 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	8 Vpp	
	Input Voltage	147 mVpp	

Tested by _____
Signature

Date 10 September 1976

A-1742
Acceptance Test Report
Equipment Set 6

A-1742

TEST DATA

SYSTEM TESTS

A1742 SERIAL NO. 006

A. Background Noise:
(With AGCs grounded, measured at -500 Pin A5) ≈45 V P-P

B. Overall Signal Characteristics and Background Noise
(50Ω Gen)

Clutter AGC	-2.15 Volts
Gain Suppression	20 dB
Background Noise	≈6 V P-P

(Measured at -500 Pin A5)

Input Level vs. Output at Monitor Ports

Input Signal = -49 dBm @ -600 Pin A1 & A2

Monitor Ports Output @ -600 A5	0.32 V P-P
-700 A5	0.5 V P-P
Input Level = -67.5 dBm	
-100 A5	0.2 V P-P
Input Level = -115 dBm	
-400 A5	0.47 V P-P
-500 A4	4.0 V P-P
-500 A5	40 V P-P

Tested by: _____
Signature

Date: 27 September 1976

TEST DATA

MODULE A1742-100 SERIAL NO. 006

	TEST	RESULT	LIMITS
1.1	Local Oscillator Frequency	✓ MHz	8.2 ± 0.05 MHz
1.2	Local Oscillator Level Set to 5 Vpp	✓ Check	Nominal
1.3	Signal Output Level	✓ Check	1 Vpp Max
1.4	Bandpass Marker 2 Frequency	10.072 MHz	
1.5	Bandpass Marker 1 Frequency	9.957 MHz	
1.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	115 KHz	110-130 KHz
1.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$	1.814 MHz	1.81-1.82 MHz
1.8	Clutter AGC Symmetry	✓ Check	
1.9	Slow AGC Symmetry	✓ Check	
1.10	Monitor Output (Percent of Signal Output)	9% Check	10% nominal
1.11	Spurious Responses	✓ Check	
1.12	Overall Gain (Slow AGC = 0) (Clutter AGC = 0)	55 dB	54-58 dB
1.13	Notch Upper 3 dB Frequency	10.0033 MHz	
1.14	Notch Lower 3 dB Frequency	9.9981 MHz	
1.15	Notch 3 dB Bandwidth ($f_{Hi} - f_{Low}$)	5.2 KHz	4.5 - 6.5 KHz
1.16	Notch Center Frequency $\sqrt{(f_{Hi})(f_{Low})} - f_{LO}$	1.80 MHz	1.8 MHz ± 100 Hz
1.17	Notch Depth	>60 dB	40 dB min
1.18	AGC Test Frequency (f signal - f_{LO})	1.815 MHz	

Tested by _____
Signature

Date 22 September 1976

TEST DATA

MODULE A1742-100 SERIAL NO. 006

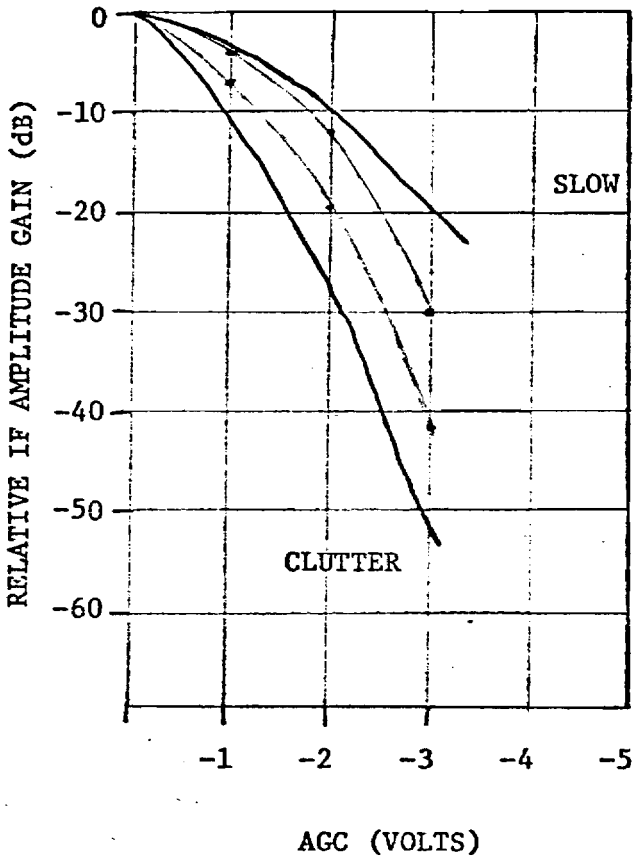
	TEST	RESULT
1.19	Gain Reduction (Slow AGC = 0V)	
	Clutter AGC = -1.0 V	-7.2 dB
	-2.0 V	-19.5 dB
	-3.0 V	-41.5 dB
1.20	Gain Reduction (Clutter AGC = 0V)	
	Slow AGC = -1.0 V	-4.5 dB
	= -2.0 V	-12 dB
	= -3.0 V	-30 dB

Tested by _____
Signature

Date 22 Sept 76

TEST DATA

Module A1742-100 Serial No. 006



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
1.21 CLUTTER AGC	0.4 V
1.22 SLOW AGC	0.5 V

TESTED BY _____
SIGNATURE

DATE 22 Sept 76

TEST DATA

MODULE A1742-100 SERIAL NO. 006

TEST	RESULT
1.23 Bandpass Response	
Clutter AGC = -3V	
Slow AGC = -3V	
Local Oscillator Frequency	8.200 MHz
Bandpass Marker 2	10.093 MHz
Bandpass Marker 1	9.955 MHz
Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	138 KHz
Bandpass Center Frequency	1.824 MHz

$\sqrt{(\text{Marker 2})(\text{Marker 1})} - f_{LO}$

Tested by _____
Signature

Date 22 Sept 76

TEST DATA

MODULE A1742-200 SERIAL NO. 006

	TEST	RESULT	LIMITS
2.1	DC Resistance		
	Pins A1-2	10 Ohms	5-15 Ohms
	A1-GND	110 Ohms	100-120 Ohms
	A2-3	9.5 Ohms	5-15 Ohms
	A2-GND	110 Ohms	100-120 Ohms
	2-GND	100 Ohms	90-110 Ohms
	3-GND	100 Ohms	90-110 Ohms
2.2	Signal Output Level	✓ Check	1 Vpp Max
2.3	Bandpass Marker 2	10.200 MHz	
2.4	Bandpass Marker 1	9.507 MHz	
2.5	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	693 KHz	595-735 KHz
2.6	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.85 MHz	9.7 - 10.0 MHz
2.7	Dip at Center of Response Curve	0.3 dB	2 dB Max
2.8	Monitor Output (Percent of Signal Output)	100% Check	100% nominal
2.9	Spurious Responses	✓ Check	
2.10	Overall Gain	32 dB	28-32 dB

Tested by _____
Signature

Date 22 September 1976

TEST DATA

MODULE A1742-200 SERIAL NO. 006

	TEST	RESULT
2.11	Bandpass Response, Gain Pot set for Max Gain	
	Bandpass Marker 2	10.180 MHz
	Bandpass Marker 1	9.507 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	673 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.84 MHz
2.12	Bandpass Response, Gain Pot set for 20 dB below Nominal Gain	
	Bandpass Marker 2	10.223 MHz
	Bandpass Marker 1	9.507 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	716 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.86 MHz

Tested by

Signature

Date 22 September 1976

TEST DATA

MODULE A1742-300 SERIAL NO. 006

	TEST	RESULT	LIMITS
3.1	Local Oscillator Frequency	1.80 MHz	1.80 ± 0.01 MHz
3.2	Local Oscillator Level	✓ Check	2.8 Vpp Nominal
3.3	Signal Output Level	✓ Check	1 Vpp Max
3.4	Frequency Marker 2	10.316 MHz	
3.5	Frequency Marker 1	9.680 MHz	
3.6	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	636 KHz	560-680 KHz
3.7	Bandpass Center Frequency $\sqrt{(\text{Marker 2})\quad(\text{Marker 1})} - f_{LO}$	8.19 MHz	8.1-8.3 MHz
3.8	Dip at Center of Response Curve	0.6 dB	2 dB Max
3.9	Monitor Output (Percent of Output Signal)	10% Check	10% Nominal
3.10	Spurious Responses	✓ Check	
3.11	Overall Gain	39 dB	38-42 dB
3.12	Limit Threshold		
	Output Voltage	7.6 Vpp	
	Input Voltage	243 mVpp	

Tested by _____ Signature

Date 22 Oct to Nov 1976

TEST DATA

MODULES A1742-400 SERIAL NO. 006

A1742-500 SERIAL NO. 006

	TEST	RESULT	LIMITS
4.1	Output Signal Level	✓ Check	8 V_{rms} Nominal
4.2	Bandpass Upper 3 dB Frequency	250.230 KHz	
4.3	Bandpass Lower 3 dB Frequency	249.751 KHz	
4.4	Bandpass Bandwidth ($f_{Up} - f_{LO}$)	479 Hz	400-500 Hz
4.5	Bandpass Center Frequency $\sqrt{(f_{Up})(f_{LO})}$	249.990 KHz	250 KHz ± 200 Hz
4.6	Discriminator Response		
	DC Output = 0 V	250.015 KHz	250 KHz ± 200 Hz
	+1 V	249.982 KHz	
	+2 V	249.955 KHz	
	+3 V	249.930 KHz	
	+4 V	249.898 KHz	
	+5 V	249.862 KHz	
	Positive Peak +5.5 V	249.836 KHz	
	-1 V	250.051 KHz	
	-2 V	250.087 KHz	
	-3 V	250.120 KHz	
	-4 V	250.151 KHz	
	-5 V	250.186 KHz	

Tested by

Signature

Date 23 September, 1976

TEST DATA

MODULES A1742-400 SERIAL NO. 006

A1742-500 SERIAL NO. 006

TEST	RESULTS	LIMITS
Negative Peak		
-5.5 V	250.212 KHz	
4.7 See Discriminator Data Plot.		
4.8 Monitor Outputs (Percent of Signal Output)		
-400 pin A5	13% Check	15% Nominal
-500 pin A4	11% Check	10% Nominal
-500 pin A5	100% Check	100% Nominal
4.9 Gain Reduction		
Fast AGC = -1.0 V	-2.2 dB	
-2.0 V	-8.2 dB	
-3.0 V	-30.5 dB	
-4.0 V	-53.2 dB	
4.10 See AGC data plot.		
4.11 Local Oscillator		
Frequency	1.57 MHz	1.5-1.6 MHz
Level	✓ Check	12 Vpp Nominal

Tested by _____

Signature

Date 23 Oct 76

TEST DATA

MODULES A1742-400 SERIAL NO. 006

A1742-500 SERIAL NO. 006

	TEST	RESULT	LIMITS
4.12	No Data Required		
4.13	Spurious Responses	✓ Check	
4.14	Overall Gain	76.5 dB	70-76 dB

Tested by _____

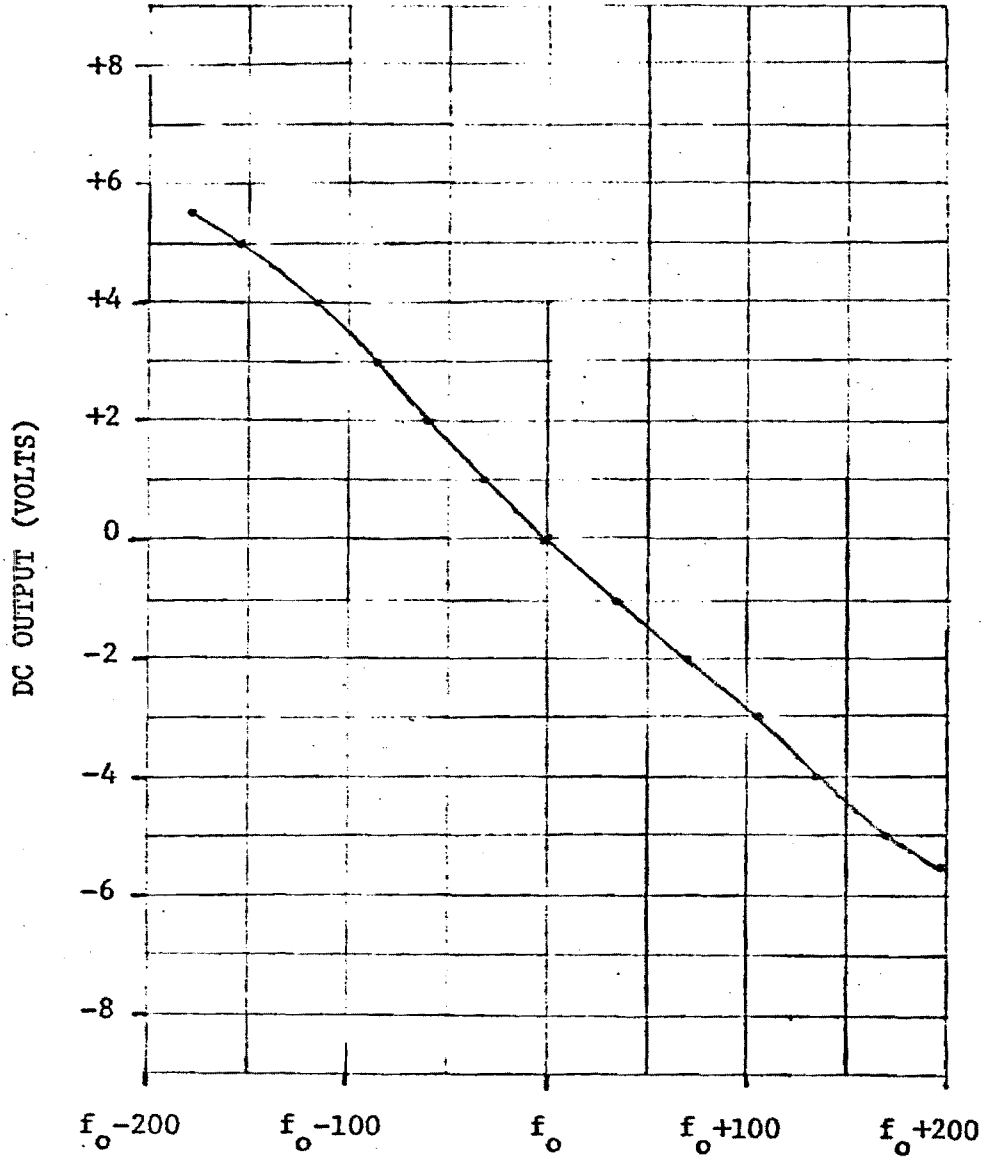
Signature

Date 23 Oct 76

TEST DATA

MODULES A1742-400 SERIAL NO. 006

A1742-500 SERIAL NO. 006



f_o = 250.015 KHz

4.7 Discriminator Response

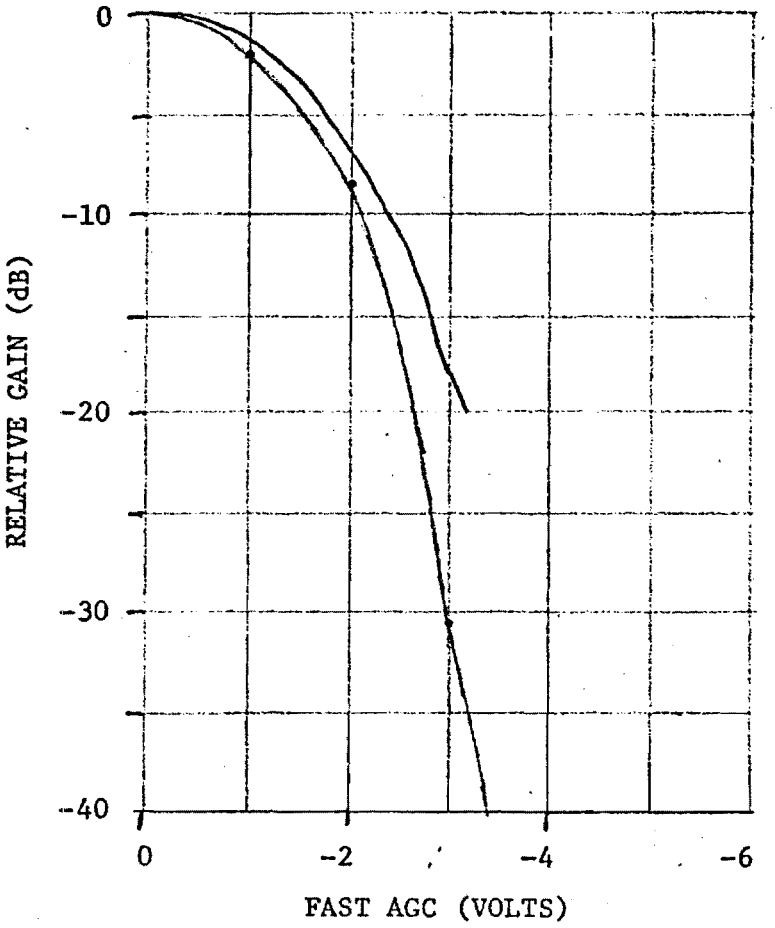
Tested by _____
Signature

Dated 28 Jul 76

TEST DATA

MODULES A1742-400 SERIAL NO. 006

A1742-500 SERIAL NO. 006



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
4.10 FAST AGC	0.5 V

TESTED BY _____
SIGNATURE

DATE 23 Apr 76

TEST DATA

MODULES A1742-400 SERIAL NO. 006

A1742-500 SERIAL NO. 006

TEST	RESULT
4.15 Bandpass Response, Fast AGC = -3V	
Bandpass Upper 3 dB Frequency	250.228 KHz
Bandpass Lower 3 dB Frequency	249.782 KHz
Bandpass Bandwidth ($f_{UP} - f_{LO}$)	446 Hz
Bandpass Center Frequency $\sqrt{(f_{UP})(f_{LO})}$	250.005 KHz

Tested by _____ Signature

Date 23 Sept 76

TEST DATA

MODULE A1742-600 SERIAL NO. 006

A1742-700 SERIAL NO. 006

TEST	RESULT	LIMITS
6.1 DC Resistance (-600 Module)		
Pins A1-2	9 Ohms	5-15 Ohms
A1-GND	109 Ohms	100-120 Ohms
A2-3	9 Ohms	5-15 Ohms
A2-GND	109 Ohms	100-120 Ohms
2-GND	100 Ohms	90-110 Ohms
3-GND	100 Ohms	90-110 Ohms
6.2 Signal Output Level	✓ Check	1 Vpp Max
6.3 Bandpass Marker 2	10.268 MHz	
6.4 Bandpass Marker 1	9.725 MHz	
6.5 Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	543 KHz	485-585 KHz
6.6 Bandpass Center Frequency		
$\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99 MHz	9.85-10.15 MHz
6.7 Dip at Center of Response Curve	0 dB	2 dB Max
6.8 Monitor Output (Percent of Signal Output)		
-600	1 X Check	1X A7 Output
-700	4.3 X Check	7X A7 Output
6.9 Spurious Responses		
-600	✓ Check	
-700	✓ Check	

Tested by _____
Signature

Date 24 September 1976

TEST DATA

MODULES A1742-600 SERIAL NO. 006

A1742-700 SERIAL NO. 006

	TEST	RESULT	LIMITS
6.10	Overall Gain	12 dB	6-10 dB
6.11	Gain Reduction		
	Slow AGC = -1.0 V	-3.1 dB	
	-2.0 V	-9.0 dB	
	-3.0 V	-22 dB	
	-3.5 V	-35 dB	
6.12	AGC Symmetry	✓ Check	

Tested by

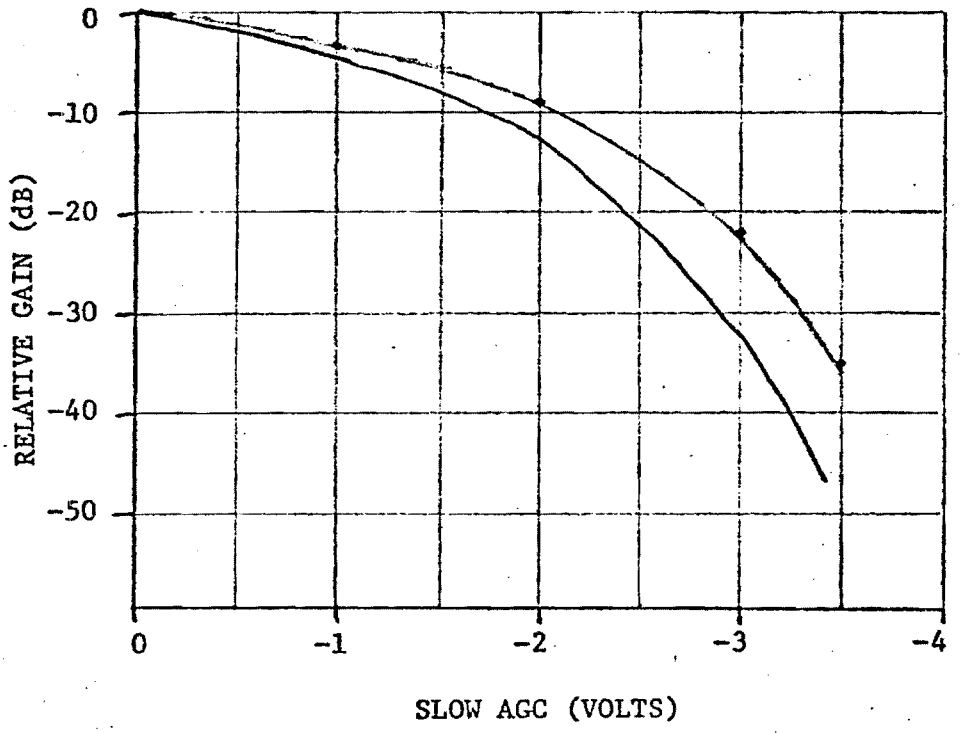
Signature

Date 24 September 1976

TEST DATA

MODULES A1742-600 SERIAL NO. 006

A1742-700 SERIAL NO. 006



TEST	RESULT
MAXIMUM DEVIATION FROM REFERENCE CURVE	
6.13 SLOW AGC	0.5 V

TESTED BY _____
SIGNATURE

DATE 24 Sept 76

TEST DATA

MODULES A1742-600 SERIAL NO. 006

A1742-700 SERIAL NO. 006

TEST		RESULT
6.14	Bandpass Response Slow AGC = -3V	
	Bandpass Marker 2	10.255 MHz
	Bandpass Marker 1	9.739 MHz
	Bandpass 3 dB Bandwidth (Marker 2 - Marker 1)	516 KHz
	Bandpass Center Frequency $\sqrt{(\text{Marker 2})(\text{Marker 1})}$	9.99 MHz

Tested by _____
Signature

Date 24 Oct 76

TEST DATA

MODULE A1742-800 SERIAL NO. 006

VCXO SERIAL NO. 6

TEST	RESULT	
8.1 Output Voltage and Frequency	1 Vrms Nominal	(1.8 MHz @ 0V +40 KHz @ -10V -40 KHz @ +10V Nominal)
Tuning Voltage (V)	Output Voltage (V)	Frequency (MHz)
-10	0.82	1.841
-8	0.85	1.832
-6	0.87	1.824
-4	0.88	1.815
-2	0.90	1.807
0	0.90	1.798
+2	0.90	1.790
+4	0.90	1.781
+6	0.88	1.772
+8	0.84	1.763
+10	0.66	1.754
8.2 Output Waveform	✓ Check	

Tested by _____
Signature

Date 23 September 1976

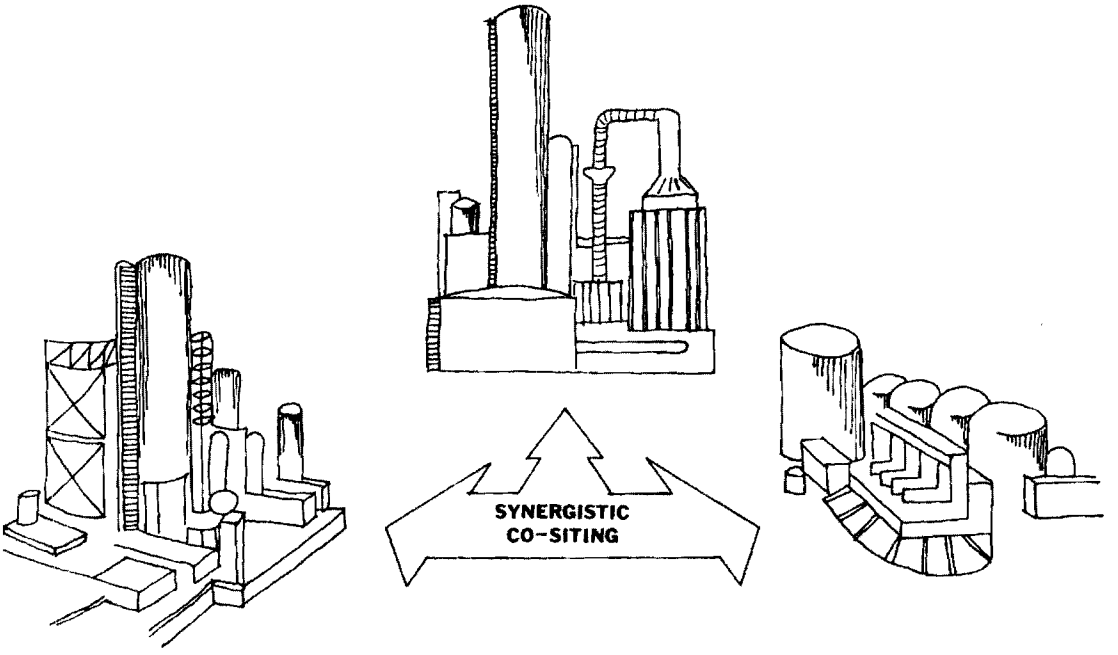
A-1772

FINAL REPORT

STUDY TO INVESTIGATE POTENTIAL BENEFITS FROM SYNERGISTIC CO–SITING OF INDUSTRIAL ACTIVITIES

By

J.M. Spurlock and H. C. Ward, Principal Investigators
J. T. Sommerfeld, J. E. Husted, and D. K. Sondhi



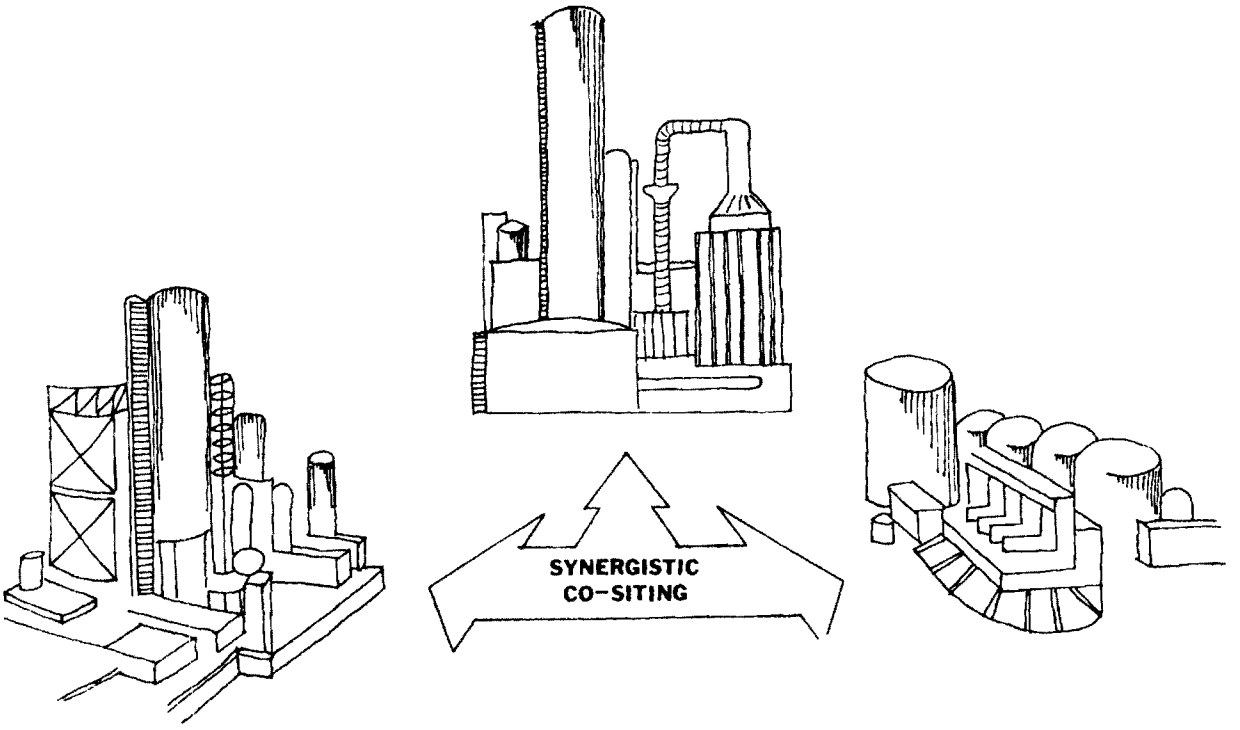
September 1976

1976

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

Appalachian Regional Commission Grant Number GA–4234–75–I–302–0509
Georgia Tech Project A–1772

STUDY TO INVESTIGATE POTENTIAL BENEFITS FROM SYNERGISTIC CO-SITING OF INDUSTRIAL ACTIVITIES



FINAL REPORT

September 1976

STUDY TO INVESTIGATE POTENTIAL BENEFITS FROM SYNERGISTIC CO-SITING OF INDUSTRIAL ACTIVITIES

Prepared for

THE APPALACHIAN REGIONAL COMMISSION

1666 Connecticut Avenue
Washington, D. C. 20235

Under

State of Georgia - ARC Grant No. GA-4234-75-I-302-0509

Submitted by

Applied Sciences Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

J. M. Spurlock and H. C. Ward, Principal Investigators
J. T. Sommerfeld
J. E. Husted
D. K. Sondhi

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EXECUTIVE SUMMARY

The purpose of this program was to elucidate and evaluate for the Appalachian Regional Commission (ARC) the potential role of synergistic co-siting (i.e., mutually beneficial location and coupling of the input and output streams) of industrial plants, and other related activities, in the forming of policies and options for energy conservation, improvement of the environment, effective land use, and economic development of appropriate regions of the State of Georgia (primary emphasis) and the Appalachian Region. The specific objectives of the program were:

(1) the identification and classification of technical factors that have the greatest influence on the selection of co-siting groupings;

(2) the screening and selection of co-siting grouping possibilities that offer significant promise for providing important resource-utilization benefits (in Georgia's Appalachian areas specifically, as well as in the Appalachian Region generally);

(3) the economic evaluation of the selected co-siting grouping examples to establish cost-benefit comparisons between conventional and co-siting methods of industrial operations;

(4) the formulation, documentation and communication of recommendations and guidelines for --

- specific co-siting groupings, for selected regions of application, to demonstrate the benefits of synergistic co-siting methodology;
- use of the methodology developed on this program as an important new tool for industrial development activities in other locations of the Appalachian Region, etc.;
- further technology developments, policy analysis, etc., that will be required to broaden the potential scope of application of synergistic co-siting and provide the necessary incentives and stimulation for implementational initiatives by prospective users.

The program was conducted for the ARC by a multidisciplinary project team from the Engineering Experiment Station (EES) of the Georgia Institute

of Technology. Throughout the program, interaction increased between the EES project staff, ARC and appropriate State of Georgia staff members, and potential industrial and government users. This interaction was important in guiding the alignment and orientation of the investigative effort and particularly useful in the selection of specific co-siting applications.

The following tasks were conducted during the course of the program:

Task I -- Data-base Development;

Task II -- Preliminary Search for Co-siting Candidates;

Task III -- Preliminary Chemical Engineering (Feasibility) Analysis for Candidates;

Task IV -- Development of Economic Model and Scaling Relationships;

Task V -- Selection of Technically Feasible Co-siting Groupings;

Task VI -- Economic Evaluation of Technically Feasible Groupings;

Task VII -- Regional Application Analysis;

Task VIII -- Formulation of Recommendations and Conclusions;

Task IX -- Initiation of Utilization Plan;

Task X -- Preparation and Distribution of Final Report.

Task I. Data-base Development

A broad spectrum of pertinent data was collected and compiled, including primary and secondary literature items on industrial plant siting technology; recent marketing and economic data and indicators for important industrial products; flowsheets, material and energy balances, and production technology for important industrial chemical processes, etc. This information was screened and developed into a reference bibliography for the project. This data-base served as the information foundation for the entire project.

Task II. Preliminary Search for Co-siting Candidates

A large number and variety of industrial processes and activities were screened, based upon the data provided by Task I. Screening criteria were developed and used to evaluate the technical- and economic-viability potential for these processes in a co-siting mode of operation. The criteria were based principally on the relative potential benefit that each process could provide or receive in a co-siting grouping, its economic growth potential over a reasonable and predictable period of time, and its potential versatility of application in a number of different co-siting grouping options.

Task III. Preliminary Chemical Engineering (Feasibility) Analysis for Candidates

This task effort was strongly coupled to the efforts on Tasks I and II. The candidate individual processes selected on Task II for further evaluation were assessed for co-siting grouping roles. Initially, sets of paired processes and/or activities were studied for feasibility and potential synergism. Subsequently, groupings consisting of larger numbers of component processes/activities were identified and evaluated. The analysis consisted principally of developing input/output (raw materials and products, energy requirements and excesses, and by-products and wastes) matrices for several of the candidate processes and activities selected on Task II, using flowsheets, material balance and energy balance information obtained on Task I. From this matrix display of process input and output data, processes were identified which have a significant degree of matching potential among their input and output streams, and fundamental technical compatibility that would facilitate the possible coupling of some of these streams. A computer technique was developed for providing the connection orders between the various plants.

Task IV. Development of Economic Model and Scaling Relationships

Results of Task IV provided a basis for determining the effects of plant size and capacity of the economic characteristics of selected candidate groupings. These results supported the economic evaluation effort on Task VI. Several sources of information relating to scaling criteria and techniques obtained on Task I were examined for validity, consistency and agreement. A large number of important processes of interest on this program were covered by the information compiled.

Task V. Selection of Technically Feasible Co-siting Groupings.

Inputs to this effort included the results derived from Tasks I, II, and III, described above. In particular, process-grouping candidates identified on Task III as having especially strong potential for matching of their input and/or output streams (to provide some important synergistic benefits), as well as apparent technical compatibility, were studied in detail regarding several key factors. These factors included: (1) capacity compatibility (i.e., the raw-material or energy requirements of one process, in the capacity range necessary to justify its operations, could be met by the by-product or waste outputs of another process operating in its optimum range of capacity); (2) technological developments or design changes required to achieve effective and efficient coupling; and (3) other operational interfacing requirements and potential problems of coupling. Once these factors were studied, those candidate groupings which still offered significant promise were characterized in a co-siting configuration by detailed flowsheets, material balances and energy balances to the extent that reliable data were available from Task I. These configurations were carefully analyzed again for design and operational feasibility and the auspicious ones were then ready for in-depth economic-viability analysis on Task VI.

Task VI. Economic Evaluation of Technically Feasible Groupings

This task included study of plant size and capacity interactions involving raw material and energy requirements, and the handling of effluents and wastes. Data from Task V were combined with cost-forecasting models to compute dollar-cost estimates of capital-investment requirements for given industrial operations. These analyses permitted the comparison of such requirements for isolated plants versus plants in various stages of complexing.

Task VII. Regional Application Analysis

This task principally involved the utilization of feedback for the development of guidelines for regional-industrial-development planning requirements which could be satisfied by this study. The procedure included:

(1) meetings with representatives of the North Georgia APDC

(2) meetings with appropriate officials of the Georgia Office of Planning and Budget and State Energy Office

(3) a workshop held at Georgia Tech in January, 1976, and attended by potential state, federal and industrial users and planners

The results of this interaction served to guide the alignment and orientation of the investigative effort, particularly in the selection of regionally-relevant co-siting groupings for evaluation.

The remaining three tasks (VIII, IX and X) served to summarize, document and communicate the essential findings and methodology of this study.

The major results of this study include:

1. Demonstration of wide range of benefits of synergistic co-siting of carefully selected industrial activities.

2. Development of methodology for obtaining and analyzing co-siting groupings for almost 100 commodities.

3. Examples of use of the methodology for several of the following co-siting modes:

   a. matching of existing plants

   b. matching of existing or proposed plants with new plants

   c. development of entirely new complexes

4. Development of guidelines, recommendations and a user-interactive computer program for potential users and planners.

5. Preparation and publication of a user manual entitled "Guidelines for Synergistic Co-siting" as a basis for the effective utilization of the methodology developed on this project.

6. Characterization of mineral resources in the Appalachian Region of Georgia as a basis for co-siting applications.

7. Identification of further study needed to broaden scope of application.

1.0 INTRODUCTION

1.1 Purpose, Objectives and Scope of the Investigation

The purpose of this program was to elucidate and evaluate for the Appalachian Regional Commission (ARC) the potential role of synergistic co-siting (i.e., mutually beneficial location and coupling of the input and output streams) of industrial plants, and other related activities, in the forming of policies and options for energy conservation, improvement of the environment, effective land use, and economic development of appropriate regions of the State of Georgia (primary emphasis) and the Appalachian Region. The specific objectives of the program were:

(1) the identification and classification of technical factors that have the greatest influence on the selection of co-siting groupings;

(2) the screening and selection of co-siting grouping possibilities that offer significant promise for providing important resource-utilization benefits (in Georgia's Appalachian areas specifically, as well as in the Appalachian Region generally);

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(4) the formulation, documentation and communication of recommendations and guidelines for --

- specific co-siting groupings, for selected regions of application, to demonstrate the benefits of synergistic co-siting methodology;
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- further technology developments, policy analysis, etc., that will be required to broaden the potential scope of application of synergistic co-siting and provide the necessary incentives and stimulation for implementation initiatives by prospective users.

The program was conducted for the ARC by a multidisciplinary project

team from the Engineering Experiment Station (EES) of the Georgia Institute of Technology. Throughout the program, interaction increased between the EES project staff, ARC and appropriate State of Georgia staff members, and potential industrial and government users. This interaction was important in guiding the alignment and orientation of the investigative effort and particularly useful in the selection of specific co-siting applications.

1.2 Background

This report describes a program of interdisciplinary study on the concept of *synergistic co-siting of industrial activities* as an important and promising approach for the solution of major national problems. Synergistic co-siting involves the carefully planned grouping of industrial and/or agricultural activities in complexes that provide mutually beneficial utilization of energy, raw materials, co-products, land, plant wastes, and transportation facilities, as well as promote greater economical attractiveness of pollution-control measures, resource recovery, etc. Practically achievable synergistic co-siting approaches to industrial-site planning, and to plant and process design, offer the promise of some very effective and exciting possibilities for the simultaneous achievement of certain critical national goals such as resources (including energy) conservation, new energy sources, effective land use, improved food supply, improved environmental quality, and beneficial industrial development.

A firm basis for co-siting has been established by a number of investigators.[1-28]*. Isard and co-workers[1-7] pioneered the method of industrial complex analysis beginning with a design in the nineteen fifties of a petrochemical complex for Puerto Rico[1]. Recently, Isard extended his methodology

*Superscript numbers identify literature citations in the List of References, Appendix A.

to include environmental management activities, with specific reference to a proposed coal power-plant complex in New York State[7]. The U. S. Atomic Energy Commission[8-12] (now ERDA and the Nuclear Regulatory Commission) and Texas A & M University[13,14] have published a number of reports and papers concerning investigations of industrial and agro-industrial complexes centered around nuclear reactors. These complexes are typically designated as "nuplexes," an acronym derived from nuclear complexes. Czamanski[15,16] and others[17,18] have focused attention on clustering of industrial activities and developing identification and analysis methods based on the use of input/output tables. Conway[19-21] has studied the grouping of related activities around waste-treatment plants and has designated such groupings as "decoplexes," which he derived from development/ecology/complexes. The Federal Energy Administration[22] has investigated the grouping of related industries in Industrial Parks, and Beller, et al.,[23] have proposed thermonuclear reactor parks. Concurrently with our study, the concept has been receiving increased attention. A recent National Science Foundation (NSF) study[24] evaluated the economic, engineering, legal, and environmental possibility of large (four to six square miles) artificial industrial-port islands located off the U. S. Atlantic and Gulf Coasts. A current NSF study[25] is investigating the potential of coal-based fuel and energy complexes for the Appalachian Region. Another current study[26] is being conducted for the ARC on a coal-gasification facility and potential gas-using industries for a specific Kentucky location. Co-product strategy[27] and integrated "coldplexes"[28] have been discussed in the recent literature, and DuPont has moved toward backward integration (see Figure 1-1).

In fact, at the present time, there are many economically sound and well-integrated industrial complexes in operation in this country and abroad. Yet,

The key in chemicals is the product mix

"There's a simple two-word answer to why chemical company earnings vary all over the lot," says Du Pont economist Charles B. Reeder. "The words are 'product mix.'"

At E. I. du Pont de Nemours & Co., the first half was sheer agony. But improving third-quarter earnings of $86 million prompted Du Pont Chairman Irving S. Shapiro to say: "I got my first good night's sleep all year."

DU PONT: A drive to assure supplies

Better control. But the shock of the first half's steep slide has prompted Shapiro and his executive committee to hustle the company down a new path—moving toward backward integration, which will give it firmer control over its raw materials. Its first big move in this direction was announced last month: Du Pont and National Distillers & Chemical Corp. will jointly build a plant to produce synthesis gas and carbon monoxide, both essential ingredients in making methanol and acetic acid, which are in turn used in plastics and fibers.

The joint deal, says Shapiro, "was made in heaven." Both companies, he points out, "need the same starting materials, and one plant is more economic than two."

Where to spend. Du Pont made a second such protective move late last month when it agreed on a 50-50 venture with Atlantic Richfield Co. to design a 100,000-bbl.-per-day oil refinery that will supply raw materials for petrochemicals. Before the energy crisis Du Pont had considered and then canceled a similar project. But now Shapiro says: "Two facts are clear. We need a secure source of supply, and our suppliers were earning more on the feedstocks they sold us than we were getting from the products we made with them."

Figure 1-1. Excerpt from Recent Pertinent Article in Literature.

while the existence of these operating complexes and the results of current and previous studies provide credibility and needed background of co-siting concepts, co-siting methodology is still in a state of development. Existing techniques of analysis may be likened to the elements of a complex itself -- each forming a part of an contributing to the whole, but none alone providing the whole methodology.

Like a complex when properly and basically designed, offering advantages over its component parts, this study was designed to combine what had gone before with new methodology to enhance the progress of this developing field of synergistic co-siting.

The modes which provided the basis for the overall approach of our study for the design of cost-effective, synergistically-coupled industrial complexes included:

(1) methods of matching existing plants within a limited geographical area.

(2) methods of matching existing or presently proposed plants with new plants.

(3) development of entirely new complexes.

Examples of the national benefits anticipated from the application of synergistic co-siting include:

- ENERGY CONSERVATION
- DEVELOPMENT OF NEW SOURCES OF FEEDSTOCKS
- ECONOMICAL RESOURCE AND WASTE RECOVERY
- IMPROVED METHODS OF (AND INCENTIVE FOR) POLLUTION CONTROL
- IMPROVED LAND USE
- OPTIMIZATION OF TRANSPORTATION USE
- ELECTRICAL-POWER COST ADVANTAGES
- IMPROVED STABILITY OF LABOR POOLS AND JOB OPPORTUNITIES
- INCREASED INCENTIVE FOR CAR-POOLING
- IMPROVED BASIS FOR USE OF HIGH-TEMPERATURE GAS-COOLED NUCLEAR POWER REACTORS

- IMPROVED BASIS FOR COMMUNITY PLANNING
- REDUCTION IN SITE-APPROVAL TIME FOR NEW PLANTS
- IMPROVED BASIS FOR ATTRACTING NEW INDUSTRY AND INCREASED PLANT-SITINGS
- MORE ECONOMICAL BASIS FOR PLANT SERVICES
- AGRICULTURAL BENEFITS
- IMPROVED PRODUCT MIX
- LOWER UNIT PRODUCT COST
- REDUCTION OF OFF-SITE FACILITIES COST

A hypothetical example of synergistic co-siting is shown in Figure 1-2.

Appropriate regions of the State of Georgia and the Appalachian Region were specified for applicational analysis in this study. The Appalachian Region is the thirteen-state area that is encompassed by the Appalachian Regional Development Act (of 1965) and, hence, the Appalachian Regional Commission (see Figure 1-3). The Appalachian Regional Commission is responsible for developing and implementing comprehensive plans for the development of Appalachia and its people. Its objectives include the improvement, on a continuing basis, of opportunities for employment, the average income level, and the standard of living for the Region through economic and social development programs that will (1) provide facilities that are needed for growth; (2) develop human resources and regional productivity; (3) develop physical and transportation resources; and (4) provide for a stable industrial system in the Region. The Commission is actively engaged in accomplishing these objectives and is particularly involved in developing information that will provide an effective basis for policy planning and the assignment of investment priorities for the implementation of its programs. Energy management, environmental improvement and effective land use, which were emphasized goals of our study, are all important goals of the Appalachian Regional Commission as well. *The rationale, then, for this study involved a systematic search for industrial combinations which offered promise for grouping synergistically in*

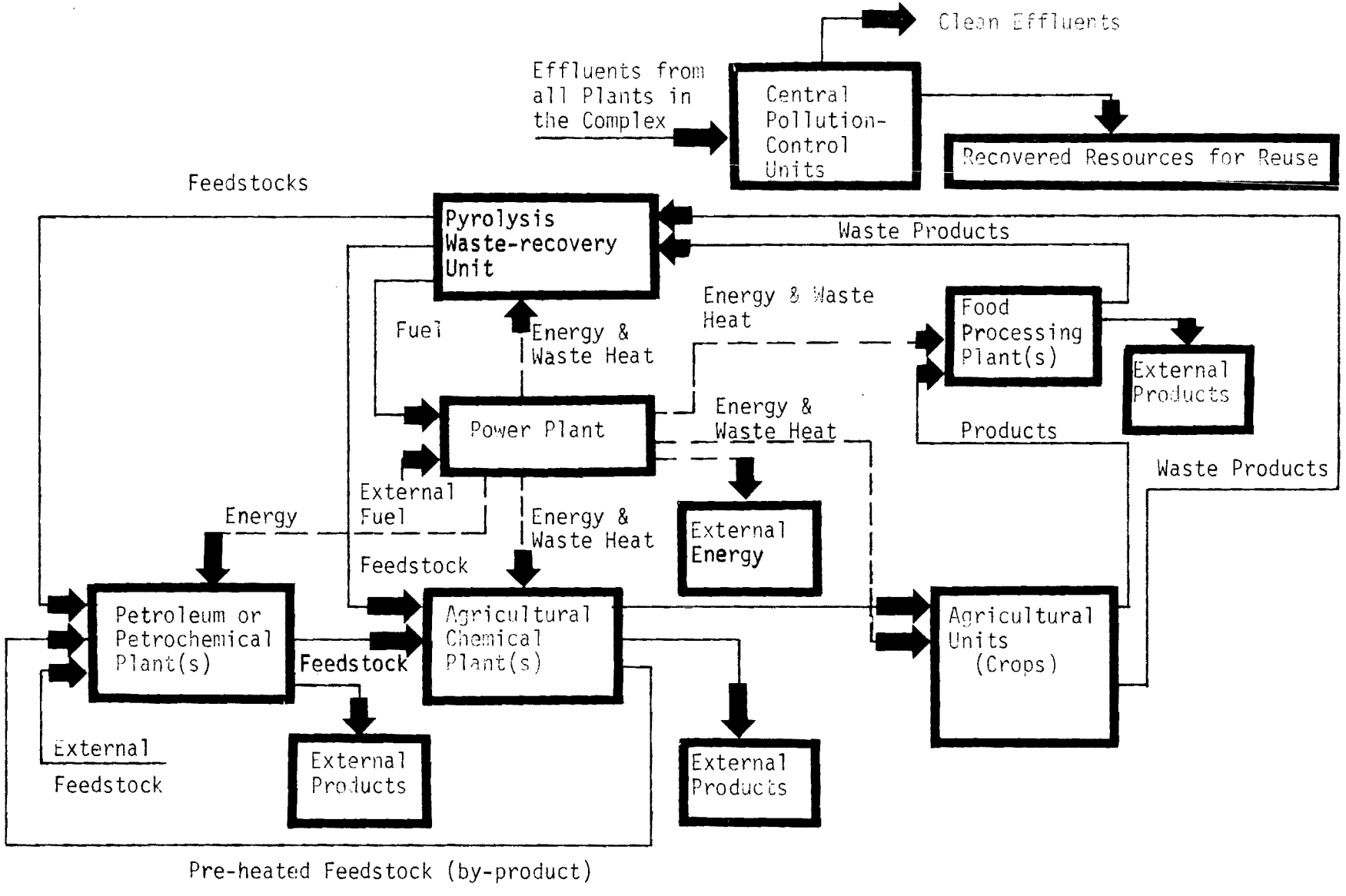


Figure 1-2. Hypothetical Example of Synergistic Co-siting Possibility.

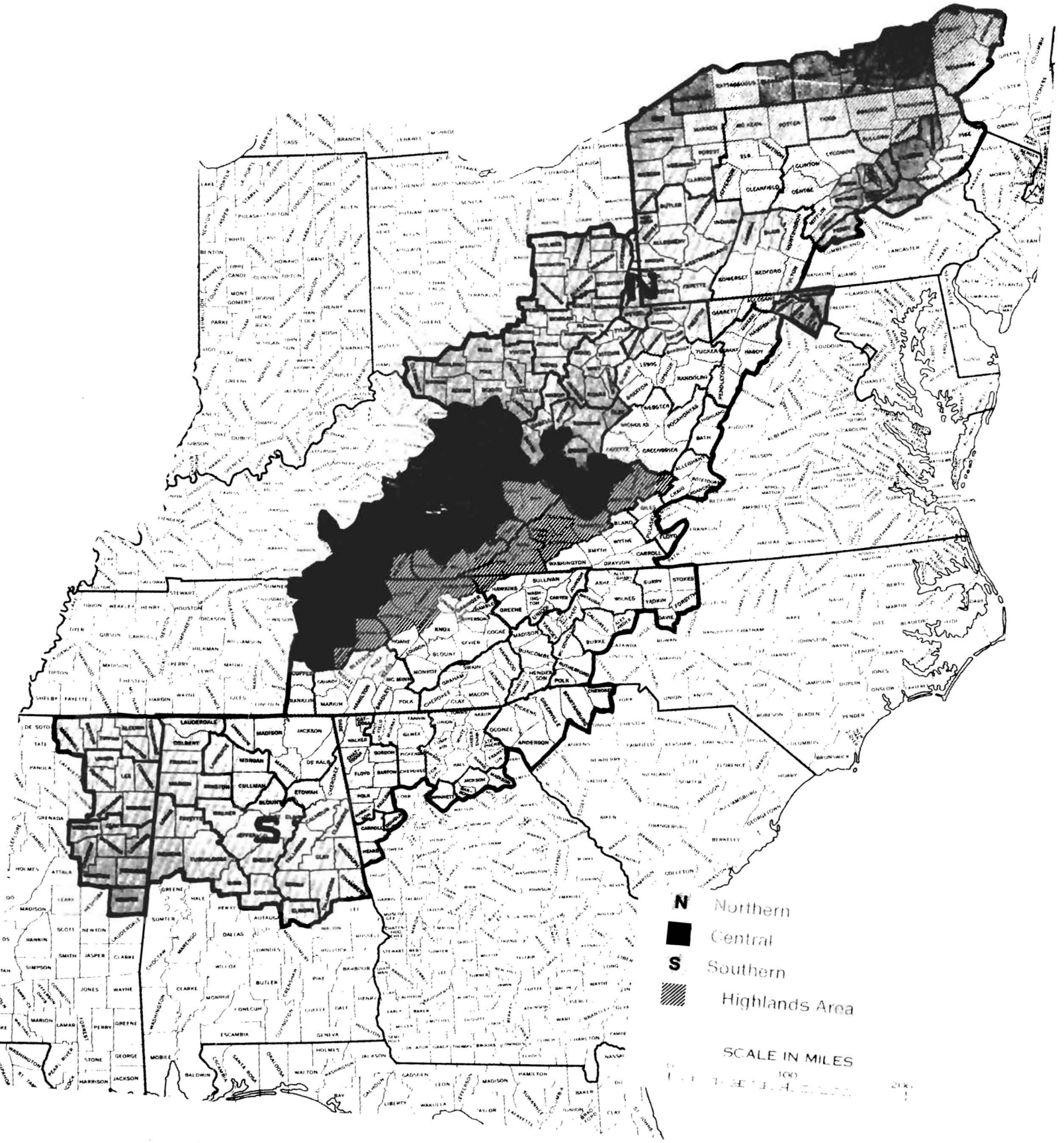


Figure 1-3. Boundaries of the Appalachian Region.

some form of co-siting to provide important energy-conservation, environmental, land use, and economic-development benefits for the region described above.

The methodology, results and essential conclusions and recommendations of this study are discussed in the remaining sections of this report.

2.0 DESCRIPTIONS OF PROJECT TASKS AND RESULTS

To meet the overall objectives, a systematic research plan consisting of ten tasks was followed. These tasks and their purposes were:

Task II -- Data-base Development

Purpose: To collect and compile technical and economic data on important industrial commodities

Task II -- Preliminary Search for Co-siting Candidates

Purpose: To scan the input-output relationships of activities in the data base and identify those with co-siting potential

Task III -- Preliminary Chemical Engineering (Feasibility) Analysis for Candidates

Purpose: To evaluate the technical and economic feasibility of the co-siting candidate sets identified in Task III and to further combine and analyze the larger groupings

Task IV -- Development of Economic Model and Scaling Relationships

Purpose: To develop expressions quantitatively relating industrial economics to plant size and production scale for commodities in the data base

Task V -- Selection of Technically Feasible Co-siting Groupings

Purpose: To methodically compare groupings of industries which, on a technical basis, could benefit from co-siting

Task VI -- Economic Evaluation of Technically Feasible Groupings

Purpose: To determine cost comparisons between isolated plants versus plants in various stages of co-siting

Task VII -- Regional Application Analysis

Purpose: To select and evaluate regionally-relevant co-siting groupings

Task VIII -- Formulation of Recommendations and Conclusions

Purpose: To develop and organize a set of useful guidelines for the application of the results and methodology developed on this study

Task IX -- Initiation of Utilization Plan

Purpose: To communicate, by way of a briefing, the results of this study to a sampling of interested users and to integrate their response into the alignment and orientation of the program

Task X -- Preparation and Distribution of Final Report

Purpose: To document procedure, results, conclusions and recommendations of this study in an effective manner

The efforts on Tasks I through VI resulted in the development of a methodology for the identification of potential co-siting candidates and analytical methods for investigation of technical and economic benefits resulting from various co-siting groupings.

The tasks, the methodology development and examples of its use are described in the following sections.

2.1 Task I -- Data-Base Development

Commodities of the chemical and petrochemical industries, with emphasis on regional raw materials and products, were chosen as the elements of the data base. Process flowsheet and economic data on almost 100 industrial chemical commodities were compiled in an organized, computerized manner. A list of the chemical commodities included in this data base is presented in Table 2-I. These various data were obtained from a thorough search of standard reference materials[29-36], as well as our extensive library files for issues of Chemical Engineering, Chemical Week, Chemical and Engineering News, Chemical Engineering Progress and Hydrocarbon Processing (technical periodicals).

A listing of the data base entries for each commodity is presented in Table 2-II; the actual data stored for one such commodity (ethylene oxide) are also shown in this table. Thus, the capital cost for a baseline plant producing 100,000 tons per year of ethylene oxide is 30 million dollars. This particular cost figure is for the year 1970, for which the Marshall-Stevens process industry index is 303.3. The current selling price of ethylene oxide is 26 cents/lb. The exponent in the power-law relationship between plant capital cost and capacity is equal to 0.78, and the production of one ton of ethylene oxide requires an electrical energy consumption of 1700 kwh. Finally, the production of one lb. of ethylene oxide (via the direct oxidation of ethylene with oxygen) requires 0.955 lb. of ethylene and 2.543 lbs. of oxygen; there is also 0.999 lb. of by-product carbon dioxide made per lb. of ethylene oxide produced.

In general, baseline plant sizes of 5-10% of current United States production were chosen for each commodity. The currently most popular processing scheme was chosen for each commodity. For some commodities not all of the requisite data were readily available. In these cases, reasonable default

TABLE 2-I

List of Chemical Commodities in the Data Base

Ethylene
Oxygen
Methanol
Carbon monoxide
Propylene
Ammonia
Chlorine
Benzene
Hydrogen
Hydrogen chloride
Acetaldehyde
Acetic acid
Acrylonitrile
Acetonitrile
Hydrogen cyanide
Ammonium nitrate
Cumene
Phenol
Acetone
Bis-phenol A
Cyclohexane
Ethanol
Ethylene oxide
Monoethanolamine
Ethylbenzene
Ethyl acetate
Formaldehyde
Isopropanol
Maleic anhydride
Methyl chloride
Nitric acid
Ethylene dichloride
Perchloroethylene
Peracetic acid
Polyethylene
BTX fraction
Toluene
Polypropylene
Ethylene glycol
Styrene
Polystyrene
Propylene oxide
Tetrahydrofuran
Carbon dioxide
Urea
Vinyl acetate
Vinyl chloride
Polyvinyl chloride
Ethane
Propane
Nitrogen
Sodium chloride
Sodium hydroxide
o-Xylene
m-Xylene
p-Xylene
Calcium carbonate
Coal
Aniline
Phthalic anhydride
Terephthalic acid
Sulfuric acid
Sodium chlorate
Melamine
Acetic anhydride
Acetylene
Calcium carbide
Calcium oxide
Coke
Trichloroethylene
Ammonium sulfate
Ammonium chloride
Nitrobenzene
Benzoic acid
Butadiene
Ethyl ether
Ethyl chloride
Sodium hypochlorite
Hydrazine
Methyl methacrylate
Sulfur
Phosgene
Sodium
Sodium sulfate
Iso-butane
Tert-Butyl alcohol
Sodium carbonate
Sodium sulfate

TABLE 2-II

Data-Base Entries for Each Commodity and Example Printout for a Specific Commodity

A. DATA BASE ENTRIES FOR EACH COMMODITY

Capacity of baseline production facility, tons/yr

Capital cost of baseline production facility, MM$

Marshall-Stevens index for the capital cost

Exponent in the power-law relationship between production plant capital cost and capacity

Selling price of the commodity, ¢/lb

Unit energy requirements for production of the commodity, kwh/ton

Raw materials requirements, lb/lb

By-product production, lb/lb

B. EXAMPLE PRINTOUT FOR A SPECIFIC COMMODITY

ETHYLENE OXIDE

```
BASELINE PLANT CAPACITY = 100000 TONS/YEAR
BASELINE PLANT COST     = 30.00 MILLION DOLLARS
CAPACITY/COST EXPONENT  =   .78
MARSHALL-STEVENS INDEX  = 303.3
SELLING PRICE           =  26.00 CENTS/LB
ENERGY REQUIREMENT      = 1700 KWH/TON

RAW MATERIAL REQUIREMENTS (LB/LB) -
   ETHYLENE                          .955
   OXYGEN                           2.543
BY-PRODUCT PRODUCTION (LB/LB) -
   CARBON DIOXIDE                    .999
```

values were assigned to some of the items listed in Table 2-II. The default value for the exponent in the power-law relationship between plant capital cost and capacity is 0.7. Similarly, the default value for baseline plant cost was computed from a value of $200 per annual ton of capacity, while a value of 200 kwh/ton was selected for the electrical energy requirement in the absence of such information. In some cases, plant capital costs and electrical energy requirements were estimated from the corresponding values for similar processing schemes.

For commodities which are by-products from the manufacture of primary products, the baseline plant cost and electrical energy requirement were set equal to zero. An example of such a by-product is carbon dioxide in Table 2-II. Similarly, the baseline plant cost and electrical energy requirement for all primary raw materials (coal, limestone, salt, etc.) were assigned values of zero (but not the selling prices thereof).

The process flowsheet information for each commodity (raw material requirements and by-product production) is used to construct a sparse, square material-balance matrix; only the non-zero entries of this matrix are supplied. Given required merchant production rates for any number of the commodities (right-hand-side vector), the resulting material-balance equations can be readily solved to yield the production rates of all intermediate commodities and total raw material requirements (activities of each of the commodities).

In this square material-balance matrix, all diagonal elements are equal to unity in that each represents the number of units of a given commodity associated with the production of itself. A negative entry at some location a_{ij} $(i \neq j)$ in the matrix represents the amount of commodity i which must be consumed to produce a unit amount of commodity j. This ratio is obtained from actual industrial experience or can be computed from the relevant stoichiometric

coefficients, molecular weights and molar yield in the relevant chemical reaction. A positive entry at location a_{ij} ($i \neq j$) denotes the amount of commodity i produced as a by-product in the manufacture of a unit amount of commodity j.

The square material-balance matrix which results is very similar to the input-output tables of classical economic theory. Specifically, the same assumptions regarding the matrix or table entries are invoked, namely, homogeneity, proportionality and additivity[37]. With the activities of the matrix equation represented by individual commodities, however, these assumptions are much more likely to be adhered to in this case. Similarly, there is no need in this analysis to perform the traditional classification and aggregation into industrial sectors as practiced in input-output methods. Finally, because of the sparse nature of the material-balance matrix, rapid solution methods for sparse matrices, as described later on, can be substituted for the cumbersome and CPU-intensive matrix inversion methods generally associated with input-output tables.

2.2 Task II -- Preliminary Search for Co-Siting Candidates

The need was recognized early in this work for a rapid and efficient method for the identification of potential co-siting candidates. Following the development of the data base described earlier, which delineates the input-output relationships between the various chemical commodities, such a procedure was devised. This procedure uses part of the data base information listed earlier, and is based upon principles of graph theory and its primary mathematical tool -- Boolean algebra. The application of Boolean algebra to the decomposition of large-scale chemical systems has been described by Himmelblau[38], and the utilization of graph theory methods to identify recycle loops in chemical systems has been presented by Crowe, et al.[29]

In this procedure, a first Boolean matrix is constructed from the relationships between inputs and outputs for the chemical commodities (e.g., raw materials, intermediate products, final products and by-products). A "true" value for a_{ij} denotes that commodity i is directly consumed in the production of commodity j, or that commodity i is formed as a by-product in the production of commodity j. Following the suggestion of Roepke, et al.[17], whereby the total interchange between industries (chemical commodities in the present case) in an aggregated transactions matrix is shown regardless of their input or output roles, a first adjacency matrix (A_1) is then formed as the sum of the first Boolean matrix and its transpose. Higher-order adjacency matrices are then constructed as successive powers of the first adjacency matrix; that is, $A_n = A^n$. In these Boolean matrix multiplications, the algorithm suggested by Lowe[40] to reduce CPU time is employed.

Successive reachability matrices are also computed as sums of all previous adjacency matrices. The n-th reachability matrix is thus given as $R_n = \sum_{i=1}^{n} A_i$. New true entries in a reachability matrix of a given order (n), and which were not present in the reachability matrix of one less order, are then extracted and examined. These new entries represent n-th order connections between the chemical commodities and suggest various possible coupling arrangements in a co-sited complex.

As a rather simple example of this procedure, consider the following sequence of chemical reactions used to manufacture several industrial chemicals:

$$C_2H_4 + \tfrac{1}{2}O_2 \longrightarrow C_2H_4O \qquad \text{(EO)}$$

$$C_2H_4O + NH_3 \longrightarrow NH_2C_2H_4OH \qquad \text{(MEA)}$$

$$C_2H_4 + \tfrac{1}{2}O_2 \longrightarrow CH_3CHO \qquad \text{(AA)}$$

Let these chemical compounds be numbered in the following fashion:

C_2H_4 - 1	NH_3 - 4
O_2 - 2	MEA - 5
EO - 3	AA - 6

The first adjacency matrix (A^1) for this system is:

$$A^1 = \begin{vmatrix} 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 \end{vmatrix}$$

where a true value of 1 for a_{ij} denotes a first-order connection between chemical materials i and j {e.g., a true value for a_{13} means that ethylene oxide (EO) is made directly from ethylene (C_2H_4)}. Note that no distinction is made as to whether (1) a given component reacts directly to form another component, or (2) a given component is directly formed from another component. This Boolean matrix is thus symmetric ($a_{ji} = a_{ij}$), and hence all succeeding adjacency and reachability matrices for this system will also be symmetric. The first reachability matrix (R_1) is, of course, identical to the first adjacency matrix.

The second adjacency matrix is formed as the Boolean product of the first adjacency matrix times itself, and appears as follows:

$$A^2 = \begin{vmatrix} 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{vmatrix}$$

The second reachability matrix is given as merely $R_2 = A^1 + A^2$, and is of the following form:

$$R_2 = \begin{vmatrix} 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 \end{vmatrix}$$

Comparing R_2 with R_1 ($= A^1$), we note the following new second-order connections between the components of this system: ethylene and oxygen, ethylene and MEA, oxygen and MEA, EO and NH_3, and EO and AA. The second-order connection between ethylene and oxygen, for example, is either through ethylene oxide (EO) or acetaldehyde (AA). Note that we ignore the trivial second-order connections between a compound and itself (corresponding to $r_{ii} = 1$).

The third adjacency matrix is the Boolean product of A^2 and A^1, that is,

$$A^3 = \begin{vmatrix} 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 \end{vmatrix}$$

Forming the third reachability matrix as $R_3 = A^3 + R_2$, we find that all of the entries of R_3, except for r_{46} and r_{64}, are true. Comparing this result with R_2, we observe the following new connections corresponding to third-order connections between these chemical compounds: ethylene and NH_3, oxygen and NH_3, and MEA and AA. The latter third-order connection is through EO, then through either C_2H_4 or oxygen, and then to acetaldehyde. If one were to form A^4 and then $R_4 = R_3 + A^4$, the entries of this fourth-order reachability matrix would all be true, disclosing a fourth-order connection between NH_3 and AA. For this reaction system, this latter connection would be the last and highest-order new connection.

2.3 Task III -- Preliminary Chemical Engineering (Feasibility) Analysis for Candidates

Having identified potential co-siting candidates according to the procedure described above, it remains to determine the technical configuration of and economic benefits resulting from co-siting of the indicated activities. At this point, information stored in the computerized data base is again employed. Having decided on merchant production rates for the various desired products, the total production rates (activities) for all of the associated chemical commodities must be determined. This is essentially a material-balance problem, employing the coefficients establishing the input-output relationships between the various chemical commodities. As mentioned earlier, the resulting coefficient matrix is sparse (population density generally less than 10%), and advantage may be taken of recently developed procedures for the reduction of sparse matrices.

The sparse matrix reduction method employed in this work is based upon the algorithm proposed by Bending and Hutchison[41]. In essence, the steps required for triangularization of the sparse matrix are delineated and memorized in an operator string of integers corresponding to element numbers. The

complete matrix is never core-resident; rather, the matrix is represented by three vectors corresponding to row locations, column locations and coefficient values for only the non-zero entries. After triangularization, a second operator string is constructed and memorized for the back-substitution steps to develop the solution vector. This method is extremely efficient in the analysis of parametric cases corresponding to various coupling-matching tests, wherein the matrix structure remains fixed, but the matrix coefficients are free to vary from case to case. The two operator strings need to be constructed only for the first case. These strings are then used to drive the solution process in this and all succeeding cases. Actual inversion of the matrix is never necessary, and the solution procedure for all parametric cases is rigorously defined and straightforward.

As an example of this sparse matrix reduction procedure, consider the solution of a system of four simultaneous equations, the coefficient matrix for which is tridiagonal:

$$\begin{vmatrix} a_1 & a_9 & & \\ a_{12} & a_2 & a_{10} & \\ & a_{13} & a_3 & a_{11} \\ & & a_{14} & a_4 \end{vmatrix} \cdot \begin{vmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{vmatrix} = \begin{vmatrix} a_5 \\ a_6 \\ a_7 \\ a_8 \end{vmatrix}$$

and where the subscripts of the coefficients pertain to their location in a vector of such elements, and not to their location in the coefficient matrix. The above matrix is admittedly not sparse; it serves well, however, as an easily visualized example of this procedure.

This coefficient matrix is triangularized by eliminating all of the

elements in the upper-right-half triangle (a_9, a_{10}, a_{11}). It has been assumed here that this matrix is non-singular and that all of the entries of the main diagonal are non-zero. The elements in the upper-right-half triangle are eliminated by proceeding row-by-row from bottom to top, and from right to left in a given row. Thus, a_{11} is first removed by adding $-a_{11}/a_4$ times the fourth row to the third row. In so doing, in this case, new values of a_3 and a_7 are created; it is also conceivable in the general case that a new element is created where none previously existed. In any event, elements a_{10} and a_9 are next eliminated in that order. The steps associated with triangularization of this matrix are summarized in Table 2-III.

Table 2-III

Steps Associated with Triangularization of Example Matrix

Element eliminated	Diagonal element	New element 1	Column element resulting in new element 1	New element 2	Column element resulting in new element 2
11	4	3	14	7	8
10	3	2	13	6	7
9	2	1	12	5	6

The three elimination steps outlined in the above table can be characterized by the following string of integers corresponding to element numbers:

-11 4 3 14 7 8 -10 3 2 13

6 7 -9 2 1 12 5 6 0

wherein a zero designates the end of the string, and a negative sign prefixing an integer denotes a new element to be eliminated. The entry following a negative entry corresponds to the diagonal element used in the elimination procedure,

and a variable number of pairs of entries following the diagonal element and preceding the next negative entry represent changes to old entries or brand new entries. In any event, if the structure of the original matrix remains unchanged, the integer string listed above represents the triangularization steps for this matrix, irrespective of any numerical changes in the coefficients of the matrix or the right-hand-side vector.

The triangularized matrix equation appears as follows:

$$\begin{vmatrix} b_1 & & & \\ b_{12} & b_2 & & \\ & b_{13} & b_3 & \\ & & b_{14} & b_4 \end{vmatrix} \bullet \begin{vmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{vmatrix} = \begin{vmatrix} b_5 \\ b_6 \\ b_7 \\ b_8 \end{vmatrix}$$

It is convenient to introduce a new variable x_{N+1}, where N is the number of rows in the original matrix, and to set $x_{N+1} = -1$. In this particular case, $x_5 = -1$. The back-substitution steps for solution of the triangularized matrix equation are then as follows:

$$x_1 = \frac{-b_5 x_5}{b_1}$$

$$x_2 = \frac{-b_6 x_5 - b_{12} x_1}{b_2}$$

$$x_3 = \frac{-b_7 x_5 - b_{13} x_2}{b_3}$$

$$x_4 = \frac{-b_8 x_5 - b_{14} x_3}{b_4}$$

These back-substitution steps are summarized in Table 2-IV.

TABLE 2-IV

Back-substitution Steps in Solution of the Triangularized Matrix Equation

Coefficient/ previous variable combinations	Number of variable solved for	Denominator coefficient number
(5 5)	1	1
(6 5) (12 1)	2	2
(7 5) (13 2)	3	3
(8 5) (14 3)	4	4

These back-substitution steps can also be represented by an integer string or operator list of element numbers as follows:

5 5 -1 1 6 5 12 1 -2 2 7 5

13 2 -3 3 8 5 14 3 -4 4 0

Again, a zero designates the end of the string, and a negative sign prefixing an integer is used to indicate the final calculations for that variable. As with the operator list for triangularization, this latter integer string remains valid irrespective of any numerical changes in the coefficients of the augmented matrix.

In an analysis of a given co-sited complex then, the activities (total production rates or raw material requirements) of all required chemical commodities are determined by solution of the associated sparse matrix equation. These activities, along with information from the stored data base, are used to develop various technical and economic results.

2.4. Task IV -- Development of Economic Model and Scaling Relationships

The total capital investment required for a given co-sited complex (inside battery limits, no off-site facilities) is determined as the sum of the individual investments required for each individual producing plant. An individual plant investment (I_2) is computed as:

$$I_2 = I_1 \left(\frac{x_2}{x_1}\right)^n \left(\frac{MS_2}{MS_1}\right)$$

where I_1 is the capital investment required to build a plant with a capacity of x_1 tons/year (baseline plant capacity) in a year in which the Marshall-Stevens index was equal to MS_1; x_2 is the required plant capacity; n is the exponent in the power-law relationship between plant capital cost and capacity; MS_2 is a current or projected Marshall-Stevens index.

The final calculations in the analysis of a given co-sited complex consist in determination of raw material costs, product values, by-product credits and power requirements. The first three of these are formed as the product of the commodity's total consumption or production rate (activity) times its current selling price. The total electric power requirement for the co-sited complex is computed (in megawatts) as the sum of the individual power requirements for each individual producing plant. The power requirement for an individual plant is determined as:

$$P \text{ (in Mw)} = \frac{x_2 E}{8.4 \cdot 10^6} .$$

where x_2 has the same significance as above; E is the unit energy consumption required to produce the given commodity, kwh/ton. The constant in the denominator is the product of two conversion factors: 1) 1000 kw/Mw and 2) an assumed value of 8400 operating hours per year (350 days) for each plant. All

of the computer programs developed in this work to implement the above calculations have been written in accordance with conventions [42] designed to improve their readability and to contain their own documentation.

2.5 Task V -- Selection of Technically Feasible Co-Siting Groupings

Ethylene has long been heralded as the backbone of the petrochemical industry. In any survey of the largest-volume synthetic chemicals in the world, it is invariably ranked as the number one organic product[27]. It is technically reasonable, therefore, to select ethylene as the core component of a co-sited complex.

Ethylene is made by the cracking of ethane or ethane/propane mixtures, various naphtha fractions, as well as from various gas oils. Plant sizes are usually quite large, of the order of a billion pounds per year. Depending upon the feedstock to the plant, various by-products are also produced, including propylene, butadiene, pyrolysis gasoline, fuel oil and a benzene-toluene-xylene (BTX) fraction. The feedstock selected in this work was a 30/70 (weight basis) mixture of ethane/propane. The various industrial chemical derivatives of ethylene include ethylene oxide, acetaldehyde, ethanol, polyethylene and vinyl chloride, among others.

Thus, a search was performed for chemical commodities, the production of which in co-sited complexes with an ethylene plant might have synergistic benefits. The mechanics of this search procedure, employing adjacency and reachability matrices, were described in the preceding sections. With almost 100 chemical commodities currently in the data base, there obviously exist large numbers of connections of various orders between the different commodities. The computer program to implement this search procedure was written so that these various connections can be screened, and only connections involving user-supplied commodities of interest are reported. This search procedure, while

very general in nature, can thus be tailored to very specific needs of an individual user and only results of interest to that user are reported. Thus, in this particular search, only connections (first-order, second-order, third-order, etc.) involving ethylene were determined. The results of this search for ethylene co-siting candidates are presented below.

First-order connections between ethylene and the other chemical commodities in the data base are summarized in Table 2-V. First-order connections generally fall into three categories. The first of these pertains to the raw materials or feedstock used in the manufacture of a given commodity. Thus, there are first-order connections exhibited between ethylene and ethane and between ethylene and propane (when an ethane/propane mixture is used as feedstock). The second category is represented by products which are directly manufactured from a given commodity. Thus, we find that ethylene exhibits a first-order connection with its various direct derivatives -- ethylene oxide, acetaldehyde, ethanol, polyethylene, ethylene dichloride, etc. Finally, a third category of first-order connections is given by the by-products or co-products (if any) associated with the manufacture of a given commodity. Again, for ethylene, examples of this type of first-order connection include propylene and the BTX fraction.

TABLE 2-V

Chemical Commodities with Which Ethylene Exhibits a First-Order Connection

Propylene	Ethane
Ethylene oxide	Ethyl chloride
Polyethylene	Ethanol
Vinyl acetate	Ethylene dichloride
Butadiene	Styrene
Acetaldehyde	Propane
Ethylbenzene	Iso-butane
BTX fraction	

In Table 2-VI are presented the second-order connections found between ethylene and the chemical commodities in the data base. In the analysis of higher-order connections and, specifically, how they originate, it becomes imperative to have a knowledge of the lower-order connections. Thus, for example, the second-order connections ethylene exhibits with polypropylene and propylene oxide are obviously through propylene. Similarly, the second-order connections with ethylene glycol and monoethanolamine are through ethylene oxide. It should also be apparent that higher-order connections between various commodities are not necessarily unique. That is, there may be several routes through which higher-order connections may be established.

TABLE 2-VI

Chemical Commodities with Which Ethylene Exhibits a Second-Order Connection

Oxygen	Perchloroethylene
Hydrogen chloride	Ethylene glycol
Cumene	Carbon dioxide
Isopropanol	Benzene
Polypropylene	Acrylonitrile
Propylene oxide	Ethyl acetate
Ethyl ether	Peracetic acid
Chlorine	Polystyrene
Acetic acid	Vinyl chloride
Monoethanolamine	

This presentation of the search procedure for ethylene concludes with a summary of third-order connections as shown in Table 2-VII. Some of these results are not quite so obvious and, hence, a bit more useful. For example, the third-order connection between ethylene and ammonia can be established through ethylene oxide and monoethanolamine. Similarly, the third-order connection between ethylene and urea is through ethylene oxide and carbon dioxide

(the latter is a by-product of ethylene oxide production and a raw material in the manufacture of urea). Some examples of fourth-order connections with ethylene include ammonium nitrate, sulfur, benzoic acid, aniline, hydrazine and calcium carbonate; fifth-order connections (highest observed) are found with formaldehyde, ammonium sulfate and sodium sulfate.

TABLE 2-VII

Chemical Commodities with Which Ethylene Exhibits a Third-Order Connection

Ammonia	p-Xylene
Hydrogen cyanide	Sodium chlorate
Maleic anhydride	Calcium oxide
Urea	Sodium hypochlorite
Sodium chloride	Tert-butyl alcohol
m-Xylene	Acetonitrile
Sulfuric acid	Cyclohexane
Acetic anhydride	Toluene
Nitrobenzene	Nitrogen
Sodium	o-Xylene
Hydrogen	Terephthalic acid
Phenol	Melamine
Methyl chloride	Ethyl acrylate
Polyvinyl chloride	Phosgene
Caustic soda	

As indicated above, propylene is generally one of the primary by-products from an ethylene plant. Propylene, in its own right, is also a very important industrial petrochemical and the precursor of many organic chemical commodities. Similarly, ammonia, normally synthesized from hydrogen and nitrogen in a catalytic reactor, is one of the more basic chemicals of the inorganic chemical industry. Hence, an analysis was made of complexes producing chemical commodities derived from propylene and ammonia.

As with the ethylene complexes investigated earlier, a search was first performed to identify potential co-siting candidates of propylene and ammonia. This search was performed in identical fashion to that for ethylene, save for propylene and ammonia serving here as the user-supplied commodities of interest. All first-order, second-order and third-order connections found between propylene and ammonia and the other commodities in the data base are shown in Tables 2-VIII, 2-IX and 2-X, respectively.

It can be seen from Table 2-VIII that both propylene and ammonia exhibit a first-order connection with acrylonitrile. Hence, acrylonitrile, in the manufacture of which acetonitrile and hydrogen cyanide are made as by-products, was selected as a co-siting candidate. Other materials selected were three ammonia derivatives -- nitric acid, ammonium nitrate and urea.

TABLE 2-VIII

Chemical Commodities with Which Propylene and Ammonia Exhibit First-Order Connections

Propylene	Ammonia
Ethylene	Hydrogen
Isopropanol	Monoethanolamine
Acrylonitrile	Nitrogen
Polypropylene	Hydrazine
Cumene	Acrylonitrile
Propylene oxide	Nitric acid
	Aniline
	Ammonium nitrate
	Urea
	Melamine

TABLE 2-IX

Chemical Commodities with Which
Propylene and Ammonia Exhibit Second-Order Connections

Propylene	Ammonia
Oxygen	Chlorine
Ammonia	Phenol
Acetaldehyde	Tetrahydofuran
Phenol	Sodium chlorate
Ethylbenzene	Isoprene
BTX fraction	Oxygen
Ethane	Propylene
Ethyl chloride	Acetonitrile
Acetonitrile	Cylcohexane
Ethanol	Carbon dioxide
Ethylene dichloride	Nitrobenzene
Styrene	Methanol
Propane	Hydrogen cyanide
Iso-butane	Ethylene oxide
Benzene	Sodium chloride
Hydrogen cyanide	Sodium hypochlorite
Ethylene oxide	
Polyethylene	
Vinyl acetate	
Butadiene	
Tert-butyl alcohol	

TABLE 2-X

Chemical Commodities with Which Propylene and Ammonia Exhibit Third-Order Connections

Propylene	Ammonia
Hydrogen	Ethylene
Ammonium nitrate	Hydrogen chloride
Cyclohexane	Acetone
Maleic anhydride	Isopropanol
Peracetic acid	Ethylene dichloride
Polystyrene	Polypropylene
Vinyl chloride	Vinyl acetate
m-Xylene	Acetylene
Melamine	Methyl methacrylate
Hydrazine	Sodium carbonate
Hydrogen chloride	Carbon monoxide
Acetone	Acetaldehyde
Monoethanolamine	Bisphenol-A
Nitric acid	Maleic anhydride
Toluene	Perchloroethylene
Carbon dioxide	Ethylene glycol
Nitrogen	Caustic sode
p-Xylene	Calcium oxide
Nitrobenzene	Phosgene
Methyl methacrylate	Benzene
Chlorine	Cumene
Acetic acid	Formaldehyde
Bisphenol-A	Methyl chloride
Ethyl acetate	Peracetic acid
Perchloroethylene	Propylene oxide
Ethylene glycol	Sulfuric acid
Urea	Ammonium chloride
o-Xylene	Sodium
Aniline	
Ethyl ether	

2.6 Task VI -- Economic Evaluation of Technically Feasible Groupings

Proceeding from the results obtained from Task V, a number of co-sited complexes were analyzed based on a) ethylene, b) propylene and ammonia, and c) ethylene, propylene and ammonia. These analyses involved utilization of the sparse matrix reduction procedure and economic calculations described earlier.

2.6.1 Ethylene-Based Complexes

Six derivatives of ethylene were selected -- acetaldehyde, ethanol, polyethylene, ethylene oxide, ethylene glycol and monoethanolamine. Merchant production figures for each of these products were first established. Typical values here amounted to 5-10% of current United States production.

Individual or isolated plants were first analyzed, and the capital costs for the plants of the given capacities were determined. These values, along with the other economic results, are summarized in Table 2-XI. It should be appreciated here that the capital costs, power requirements, etc., associated with each of the six production facilities listed in this table include all of the supporting plants as well (e.g., ethylene plant, oxygen plant, ammonia plant, as needed).

The first levels of co-siting (C_1 and C_2) are indicated in Figures 2-1 and 2-2. In complex C_1, acetaldehyde, ethanol and polyethylene are produced; ethylene oxide, monoethanolamine and ethylene glycol are produced in complex C_2. The results of analysis of these two complexes are presented in Table 2-XII. There is a reduction in total capital investment from 308.2 to 255.7 million dollars resulting from this first co-siting arrangement (most of this reduction results from the usage of larger ethylene plants in these two complexes). There is, as yet, no synergistic usage of by-products or co-products in these complexes and, hence, the totals of the by-product credits

TABLE 2-XI

Results of Analysis of Individual Plants Producing Ethylene Derivatives

PRODUCT	PRODUCTION RATE, tons/yr	CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Acetaldehyde	75,000	26.7	24.0	6.9	5.3	5.0
Ethanol	100,000	32.2	40.0	3.8	7.2	3.7
Polyethylene	100,000	90.3	56.0	5.7	10.8	13.6
Ethylene oxide	100,000	76.6	52.0	40.7	10.0	34.9
Monoethanolamine	20,000	23.0	14.4	6.3	1.6	6.1
Ethylene glycol	100,000	59.4	53.0	28.9	7.1	24.8
	TOTALS:	308.2	239.4	92.3	42.0	88.1

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

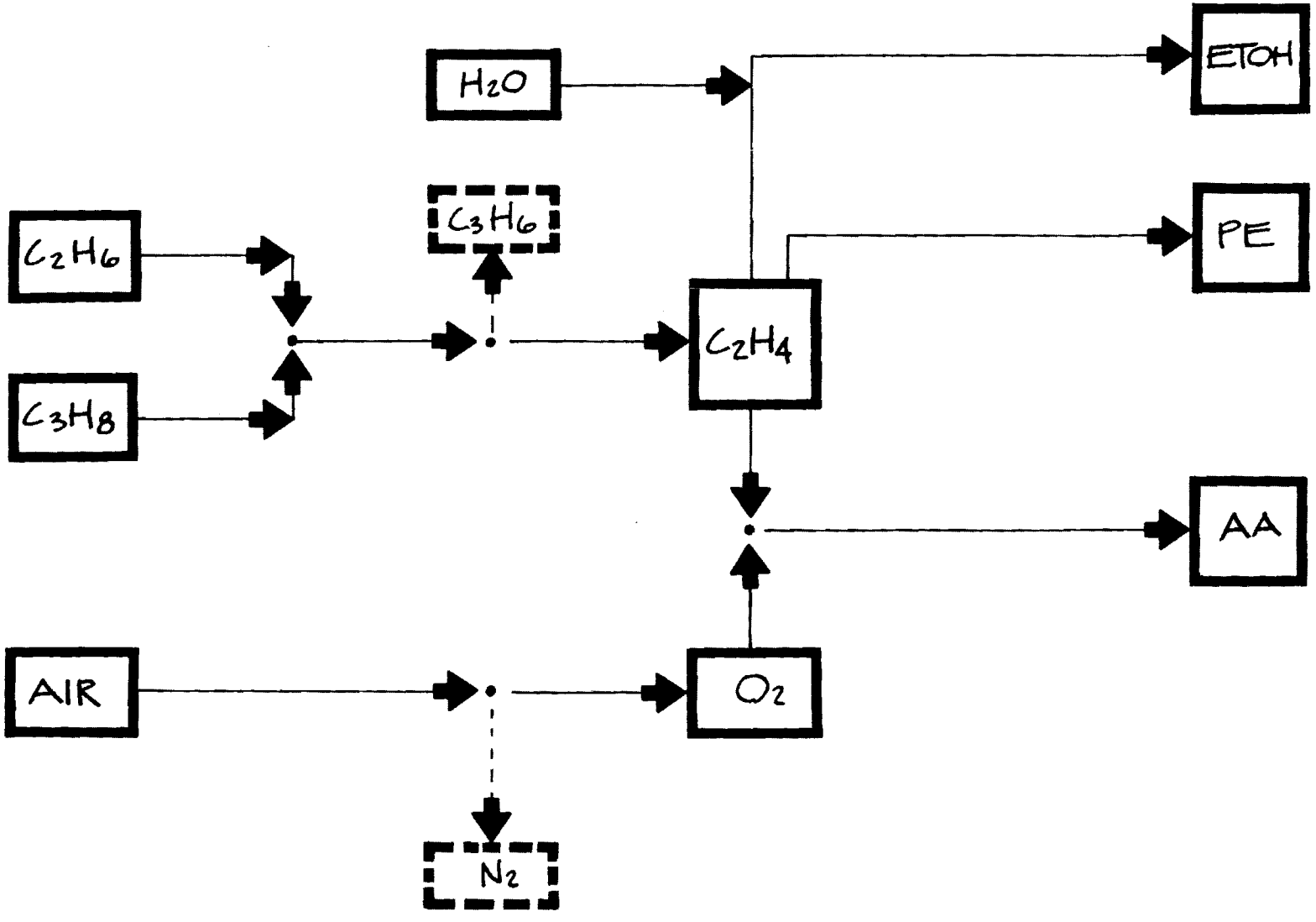


Figure 2-1. First Level of Co-Siting of Plants Producing Ethylene Derivatives, Complex C_1.

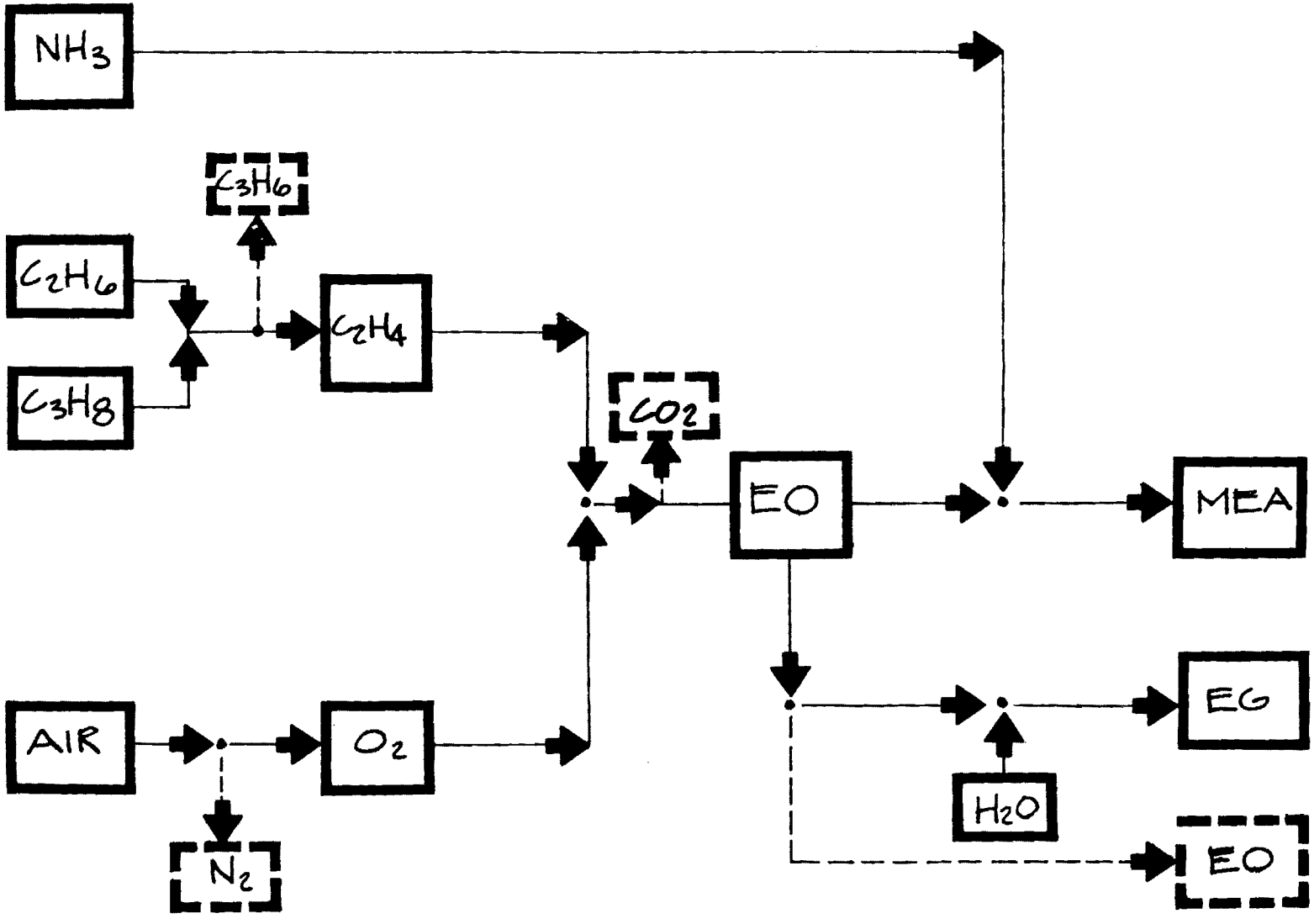


Figure 2-2. First Level of Co-Siting of Plants Producing Ethylene Derivatives, Complex C_2.

TABLE 2-XII

Results of Analysis of First Level of Co-siting of Plants Producing Ethylene Derivatives

PRODUCT	PRODUCTION RATE, tons/yr		CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Acetaldehyde	75,000						
Ethanol	100,000	C_1 →	130.6	120.0	16.3	23.2	22.3
Polyethylene	100,000						
Ethylene oxide	100,000						
Monoethanolamine	20,000	C_2 →	125.1	119.4	76.0	18.7	65.9
Ethylene glycol	100,000						
	TOTALS		255.7	239.4	92.3	41.9	88.2

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

and raw material costs remain unchanged. Similarly, since the relationship between production rate and energy consumption is a linear one, there is no change in the total power requirements.

A more realistic arrangement is given in the second level of co-siting -- complex C_{12} in Figure 2-3. This complex produces all of the ethylene-based chemicals shown in Tables 2-XI and 2-XII. The results of analysis of this single complex are presented in Table 2-XIII. The total capital investment required for this complex reduces to 237.6 million dollars. Again, there is no change in the totals of the by-products and raw material costs. The synergistic usage of by-products as raw materials will be illustrated in a later example.

TABLE 2-XIII

Results of Analysis of Second Level of Co-siting of Plants Producing Ethylene Derivatives (Complex C_{12})

Total capital cost*, MM$	237.6
Total value of products, MM$/yr	239.4
Total by-product credits, MM$/yr	92.3
Total raw material costs, MM$/yr	42.0
Total power requirements, Mw	88.2

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

2.6.2 Complexes Based on Propylene and Ammonia

As with the ethylene derivatives, individual or isolated plants were first examined. The raw materials to these plants or complexes thereof consisted of propylene, nitrogen and hydrogen; ammonia was manufactured in the amounts required. The results of this analysis of the individual producing

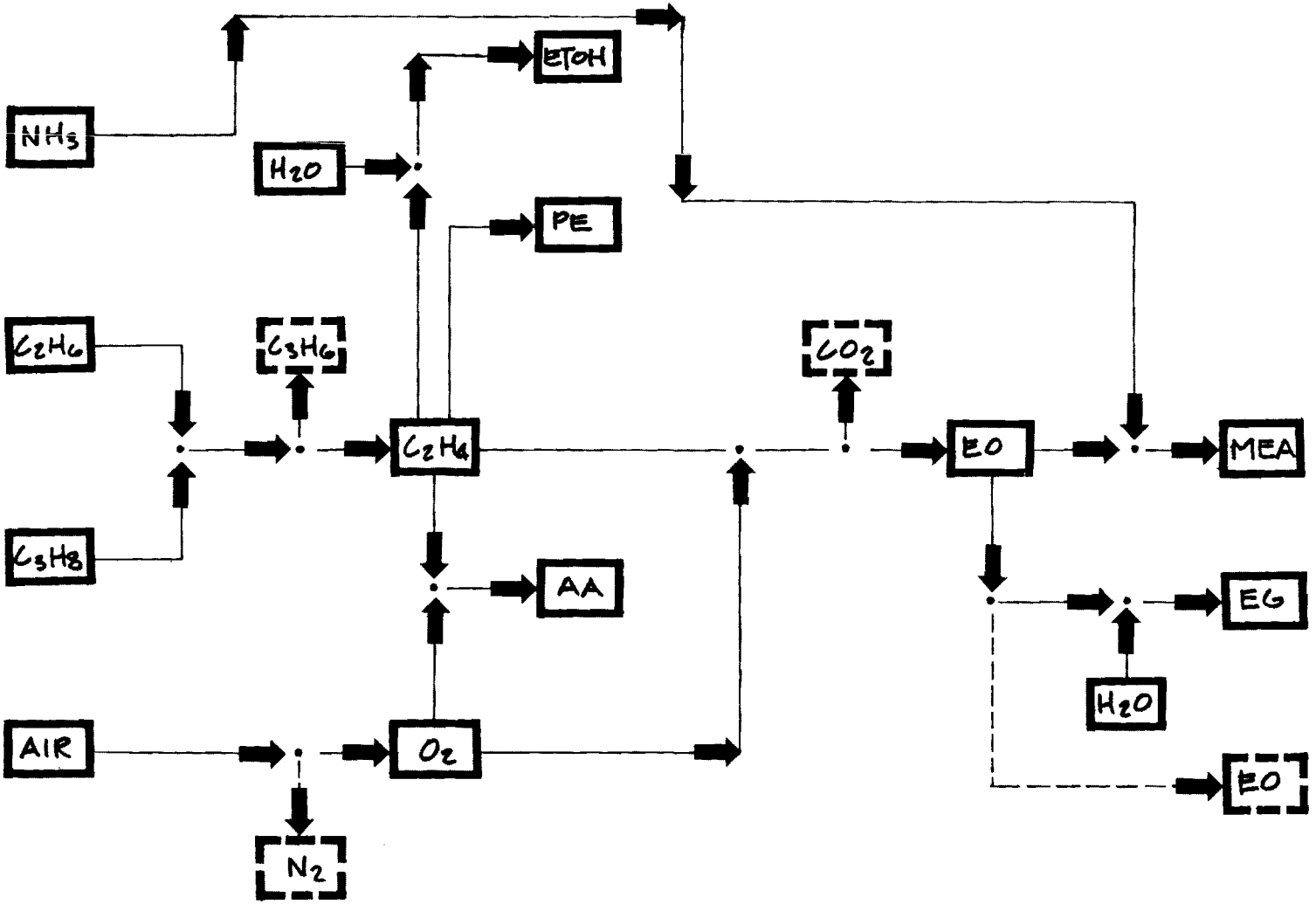


Figure 2-3. Second Level of Co-Siting of Plants Producing Ethylene Derivatives, Complex C_{12}.

plants are summarized in Table 2-XIV.

The first level of co-siting of these propylene and ammonia derivatives consisted of one complex (C_3) to manufacture acrylonitrile and urea and a second complex (C_4) to manufacture ammonium nitrate and nitric acid (see Figures 2-4 and 2-5, respectively). The results of analysis of these two complexes are presented in Table 2-XV. A reduction in the total capital investment required from 73.8 to 69.8 million dollars is observed here; most of this reduction results from the usage of larger ammonia plants in these two complexes.

The next level of co-siting (C_{34}) is indicated in the scheme of Figure 2-6, in which all of the propylene and ammonia derivatives are produced at one site. The results of analysis of this complex are summarized in Table 2-XVI. There is a further reduction here in the total capital investment down to 67.0 million dollars. As with the complex producing all of the ethylene derivatives, there is no change in the totals of the by-product credits or the raw material costs indicating, as yet, no synergistic usage of by-products or co-products.

2.6.3. Complexes Based on Ethylene, Propylene and Ammonia

Since propylene is a direct by-product of ethylene manufacture, it seems logical to integrate the production of ethylene derivatives with the manufacture of the derivatives of propylene and ammonia. Such a fully integrated co-sited complex, producing all ten (six ethylene derivatives, four derivatives of propylene and ammonia) of the chemicals (C_{1234}), is shown in Figure 2-7; the results of analysis of this fully integrated complex are summarized in Table 2-XVII. Comparing the results of this table with the sums of results from Tables 2-XIII and 2-XVI (complexes C_{12} and C_{34}, respectively), one finds very little reduction in the total capital investment required -- 304.0

TABLE 2-XIV

Results of Analysis of Individual Plants Producing Derivatives of Propylene and Ammonia

PRODUCT	PRODUCTION RATE, tons/yr	CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Acrylonitrile	50,000	34.7	24.0	4.6	9.9	1.5
Urea	150,000	21.6	24.0	0.0	16.8	6.0
Ammonium nitrate	100,000	8.9	9.1	0.0	2.2	4.7
Nitric acid	175,000	8.6	36.8	0.0	2.4	7.9
	TOTALS	73.8	93.9	4.6	31.3	20.1

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

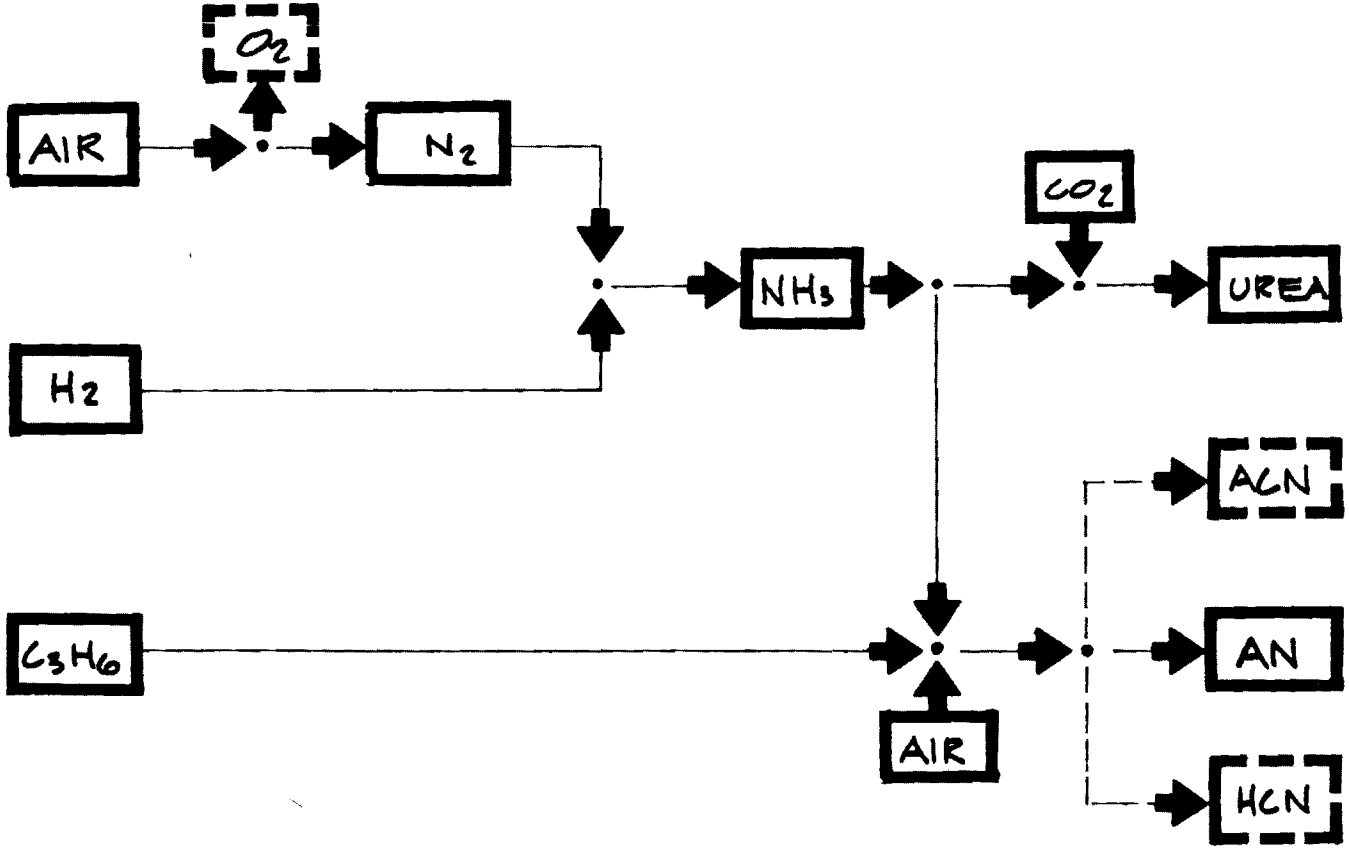


Figure 2-4. First Level of Co-Siting of Plants Producing Derivatives of Propylene and Ammonia, Complex C_3.

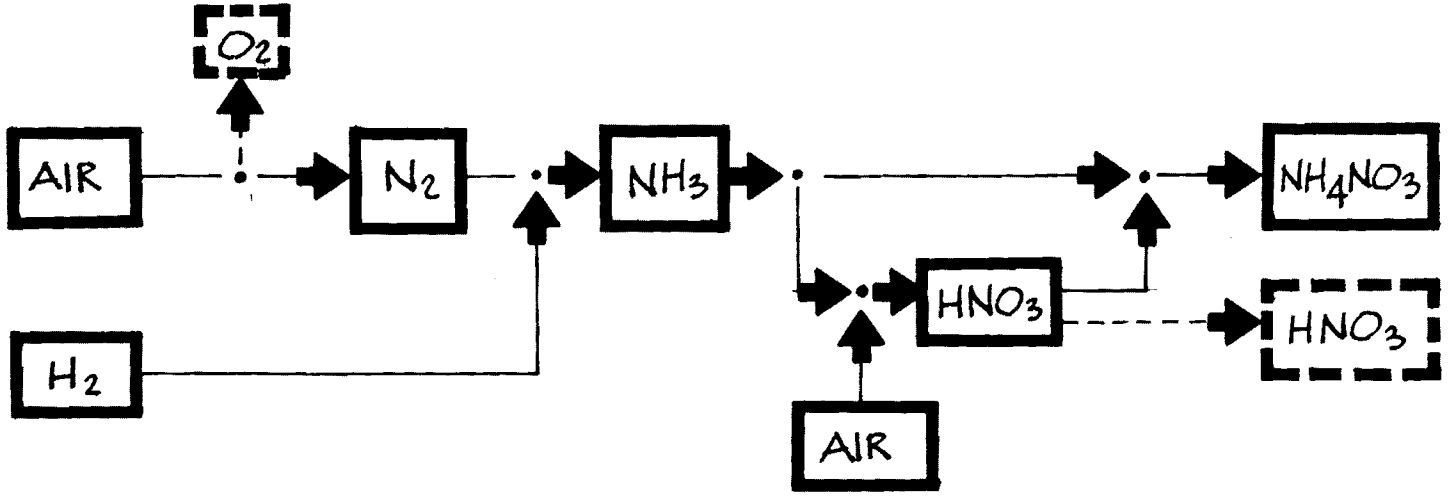


Figure 2-5. First Level of Co-Siting of Plants Producing Derivatives of Propylene and Ammonia, Complex C_4.

TABLE 2-XV

Results of Analysis of First Level of Co-siting of Plants Producing Derivatives of Propylene and Ammonia

PRODUCT	PRODUCTION RATE, tons/yr	CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Acrylonitrile	50,000					
		$C_3 \rightarrow$ 54.9	48.0	4.6	26.7	7.5
Urea	150,000					
Ammonium nitrate	100,000					
		$C_4 \rightarrow$ 14.9	45.9	0.0	4.6	12.6
Nitric acid	175,000					
	TOTALS	69.8	93.9	4.6	31.3	20.1

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

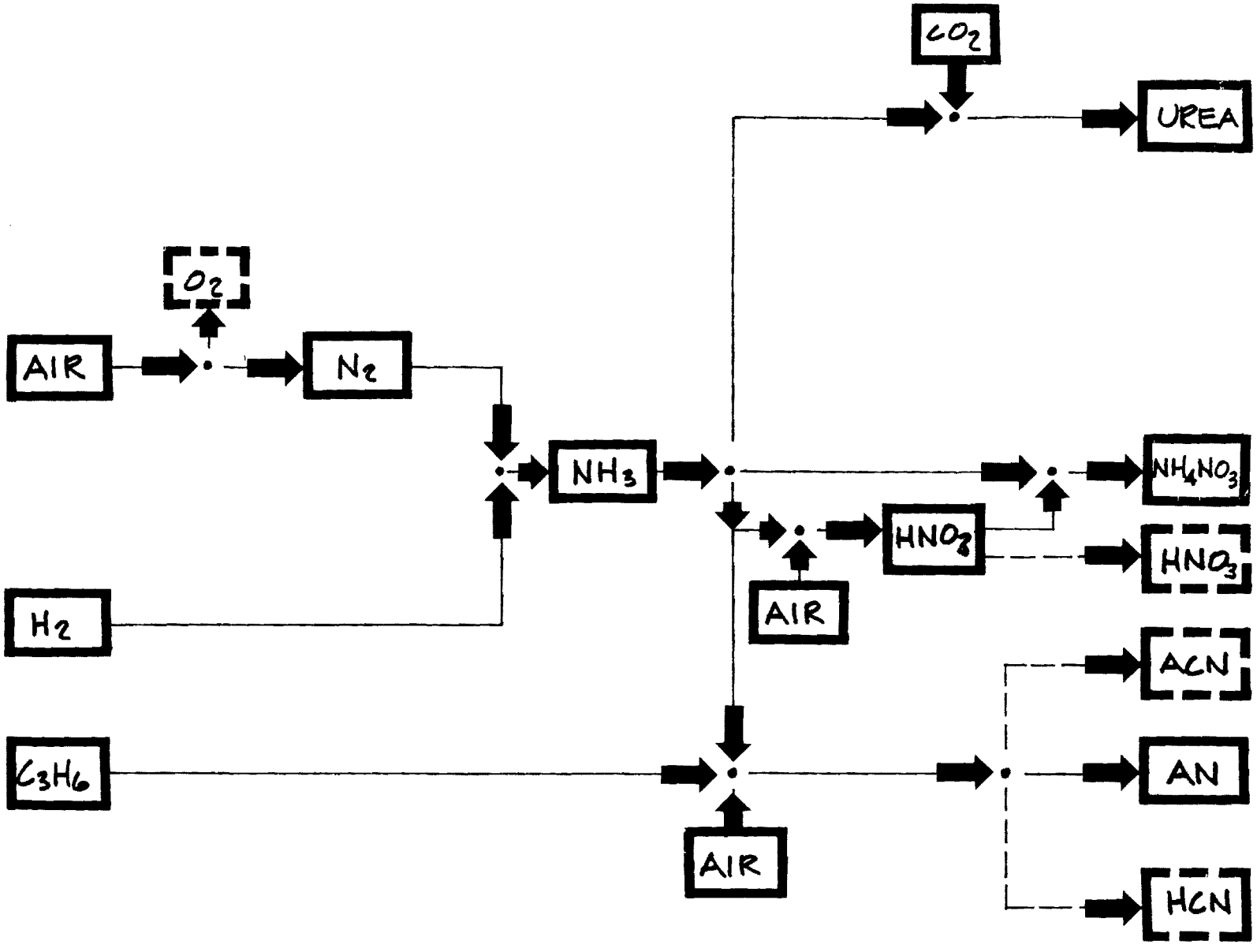


Figure 2-6. Second Level of Co-Siting of Plants Producing Derivatives of Propylene and Ammonia, Complex C_{34}.

TABLE 2-XVI

Results of Analysis of Second Level of Co-siting of Plants Producing Derivatives of Propylene and Ammonia (Complex C_{34})

Total capital cost*, MM$	67.0
Total value of products, MM$/yr	93.9
Total by-product credits, MM$/yr	4.6
Total raw material costs, MM$/yr	31.3
Total power requirements, Mw	20.1

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

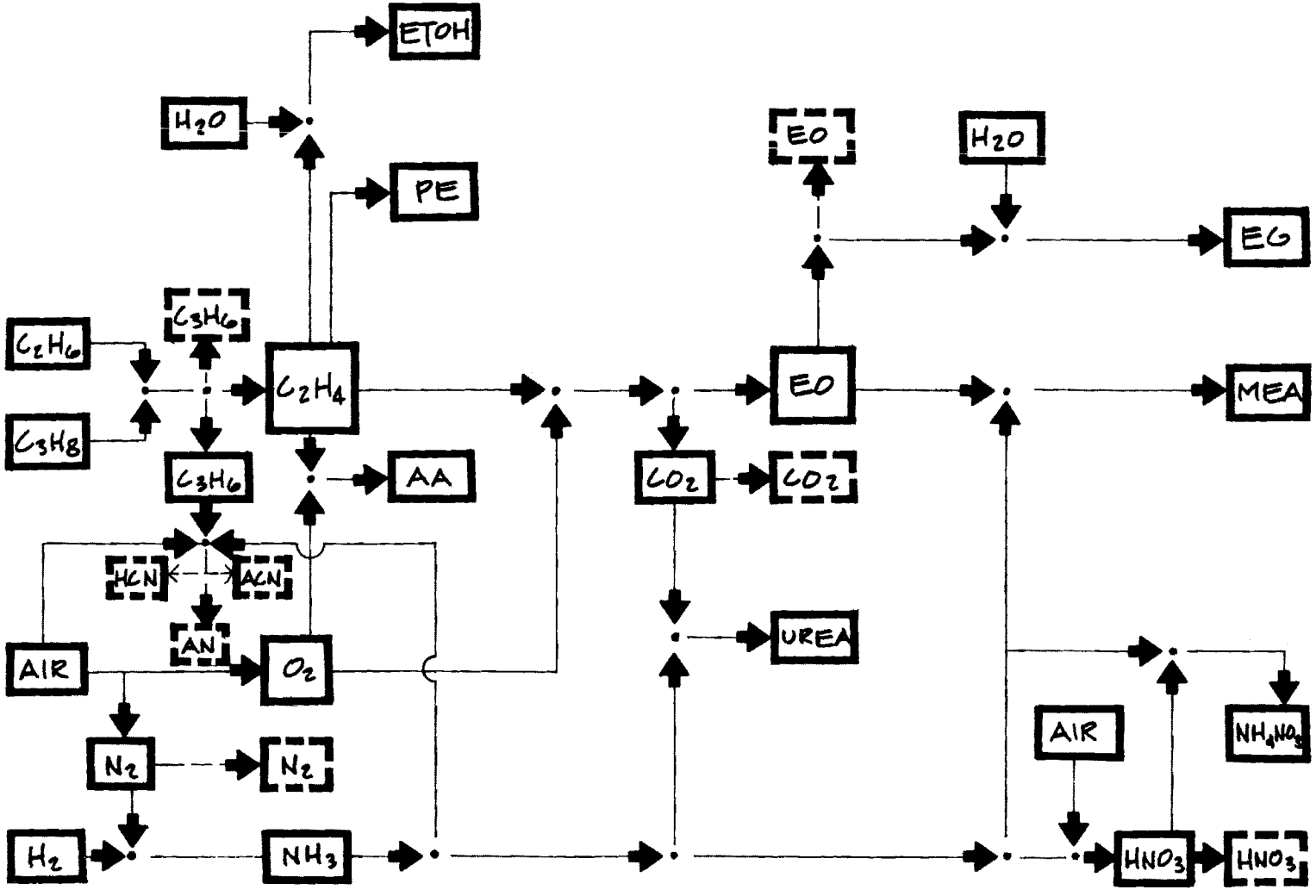


Figure 2-7. Fully Integrated Co-Sited Complex for Producing Derivatives of Ethylene, Propylene and Ammonia, Complex C_{1234}.

TABLE 2-XVII

Results of Analysis of a Fully Integrated Co-sited Complex of Plants Producing Derivatives of Ethylene, Propylene and Ammonia (Complex C_{1234})

Total capital cost*, MM$	304.0
Total value of products, MM$/yr	333.3
Total by-product credits, MM$/yr	69.1
Total raw material costs, MM$/yr	45.5
Total power requirements, Mw	108.3

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

million dollars for the fully integrated complex versus 304.6 for the sum of the two sub-complexes. A summary of the capital investment costs associated with the individual plants and various levels of co-siting of plants for producing the derivatives of ethylene, propylene and ammonia is given in Table 2-XVIII.

There is, however, considerable synergistic usage of co-products and by-products in the fully integrated complex. Again comparing the results of Table 2-XVII with the sums of results from Tables 2-XIII and 2-XVI, the total by-product credits are seen to reduce from 96.9 to 69.1 million dollars per year in the case of the fully integrated co-sited complex. Similarly, the total raw material costs reduce from 73.3 to 45.5 million dollars per year. Specific examples of by-product and co-product usage here include the oxygen plant required for acetaldehyde and ethylene oxide production, and which also produces nitrogen which is used in the manufacture of ammonia. The ethylene plant, of course, also produces the propylene required for the manufacture of acrylonitrile. The ammonia plant which is the precursor of the ammonia derivatives also supplies the ammonia required in the manufacture of monoethanolamine. Finally, the by-product carbon dioxide made in the ethylene oxide plant is used as a feedstock to the urea plant.

TABLE 2-XVIII. Cost Comparisons Between Individual Plants and Various Co-siting Levels for Producing Derivatives of Ethylene, Propylene and Ammonia

Plant	Isolated Operations		First Level of Co-Siting	Second Level of Co-Siting	Fully Integrated Co-Siting
	Capacity (tons/yr)	Cost* (MM$)	Cost* (MM$)	Cost* (MM$)	Cost* (MM$)
Acetaldehyde (AA) (CH_3CHO)	75,000	26.7			
Ethanol (ETOH) (C_2H_5OH)	100,000	32.2	C_1 → 130.6		
Polyethylene (PE) ($(C_2H_4)_x$)	100,000	90.3		C_{12} → 237.6	
Ethylene oxide (EO) (C_2H_4O)	100,000	76.6			
Ethylene Glycol (EG) (CH_2OHCH_2OH)	100,000	59.4	C_2 → 125.1		
Monoethanolamine (MEA) ($NH_2C_2H_4OH$)	20,000	23.0			C_{1234} → 304.0
Urea (Urea) ($CO(NH_2)_2$)	150,000	21.6	C_3 → 54.9		
Acrylonitrile (AN) (CH_2CHCN)	50,000	34.7		C_{34} → 67.0	
Nitric acid (NA) (HNO_3)	175,000	8.6	C_4 → 14.9		
Ammonium nitrate (AMN) (NH_4NO_3)	100,000	8.9			
		382.0	325.5	304.6	304.0

* Capital cost only. Not included are offsite facilities, land costs and utilities.

2.7 Task VII - Regional Application Analysis

In Task VI, general applications of the methodology developed in this study were presented. These applications demonstrate the power and flexibility of the methodological tools in the identification and analysis of potential co-sited complexes (in this case, chemical in nature, but certainly not restricted thereto). Under this Task, analyses of co-sited complexes of chemical plants based upon raw materials abundant in the Appalachian Region were made. This abundancy evaluation was based upon a review of mineral resources in the Appalachian Region. In particular, the raw materials consisted of coal, salt and limestone. As a basis for additional co-siting applications, a compilation of mineral resources in the Appalachian Region of Georgia is presented in Appendix B.

2.7.1 Coal-Based Complexes

Coal is certainly the most abundant raw material in the Appalachian Region. Originally the basis of the organic chemical industry and then supplanted by petroleum, it has, with the advent of the energy crisis and related problems, re-emerged as a leading candidate for the manufacture of synthetic fuels and organic raw materials[43]. Coke has always, of course, been an important derivative of coal. Renewed interest in coal gasification with steam may lead to large-scale manufacture of carbon monoxide and by-product hydrogen via this route. Such a coal gasification scheme was incorporated into the data base and input-output matrix of this work. The required data for this purpose were obtained from a recent review of carbon monoxide production methods[44].

As for the ethylene-based complexes investigated earlier, a search was first performed to identify potential co-siting candidates based upon coal. A summary of the first-order connections exhibited by coal with the other

chemical commodities in the data base is given in Table 2-XIX. The obvious first-order connections with coke and carbon monoxide are shown therein. All second-order connections with coal are presented in Table 2-XX. The second-order connections exhibited with methanol and phosgene are obviously through carbon monoxide. Similarly, the second-order connection with calcium carbide is through coke. Third-order connections involving coal are summarized in Table 2-XXI. The third-order connection exhibited with formaldehyde is obviously through carbon monoxide and then methanol. Similarly, the third-order connection with acetylene is through coke and then calcium carbide.

Proceeding from the results of this search, plants and complexes thereof producing coal derivatives were analyzed. The following seven products were selected: coke, methanol, formaldehyde, calcium carbide, phosgene, acetylene and isoprene. Merchant production figures for each of these products were first selected, and individual or isolated plants for manufacturing these products were then analyzed. The results of this economic analysis are presented in Table 2-XXII. The capital costs, raw material costs and power requirements shown for the manufacture of each of the products in this table also include those for all of the supporting plants as well (e.g., coal gasification plant, lime plant, chlorine plant, methanol plant for formaldehyde manufacture, etc.).

The first levels of co-siting (C_5 and C_6) are indicated in Figures 2-8 and 2.9. In complex C_5, coke, methanol and formaldehyde are produced; calcium carbide, phosgene, acetylene and isoprene are produced in complex C_6. The results of analysis of these two complexes are shown in Table 2-XXIII. A significant reduction in the total capital investment from 402.9 to 351.9 million dollars is observed here. This decrease results from several factors -- a larger co-sited coal gasification plant and also larger co-sited plants for the manufacture of materials which serve as both intermediate and final products,

TABLE 2-XIX

Chemical Commodities with Which
Coal Exhibits a First-Order Connection

Carbon monoxide

Coke

Calcium oxide

TABLE 2-XX

Chemical Commodities with Which
Coal Exhibits a Second-Order Connection

Methanol

Carbon dioxide

Sulfuric acid

Ammonium sulfate

Hydrogen

Calcium carbonate

Calcium carbide

Phosgene

TABLE 2-XXI

Chemical Commodities with Which
Coal Exhibits a Third-Order Connection

Ammonia	Chlorine
Cyclohexane	Ethylene oxide
Formaldehyde	Maleic anhydride
Methyl chloride	Tetrahydrofuran
Urea	Sodium chlorate
Melamine	Acetylene
Ammonium chloride	Ethyl ether
Methyl methacrylate	Sulfur
Isoprene	

TABLE 2-XXII

Results of Analysis of Individual Plants Producing Coal Derivatives

PRODUCT	PRODUCTION RATE, tons/yr	CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Coke	1,000,000	102.8	40.0	0.7	29.4	1.3
Methanol	300,000	56.4	36.4	0.0	4.9	20.0
Formaldehyde	150,000	80.1	36.5	0.0	3.1	16.1
Calcium carbide	100,000	36.9	17.1	3.5	3.5	34.9
Phosgene	50,000	27.9	25.0	15.8	3.1	14.6
Acetylene	50,000	55.3	49.0	3.6	3.6	53.3
Isoprene	40,000	43.5	56.0	1.3	14.1	21.8
	TOTALS	402.9	260.0	24.9	61.7	162.0

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

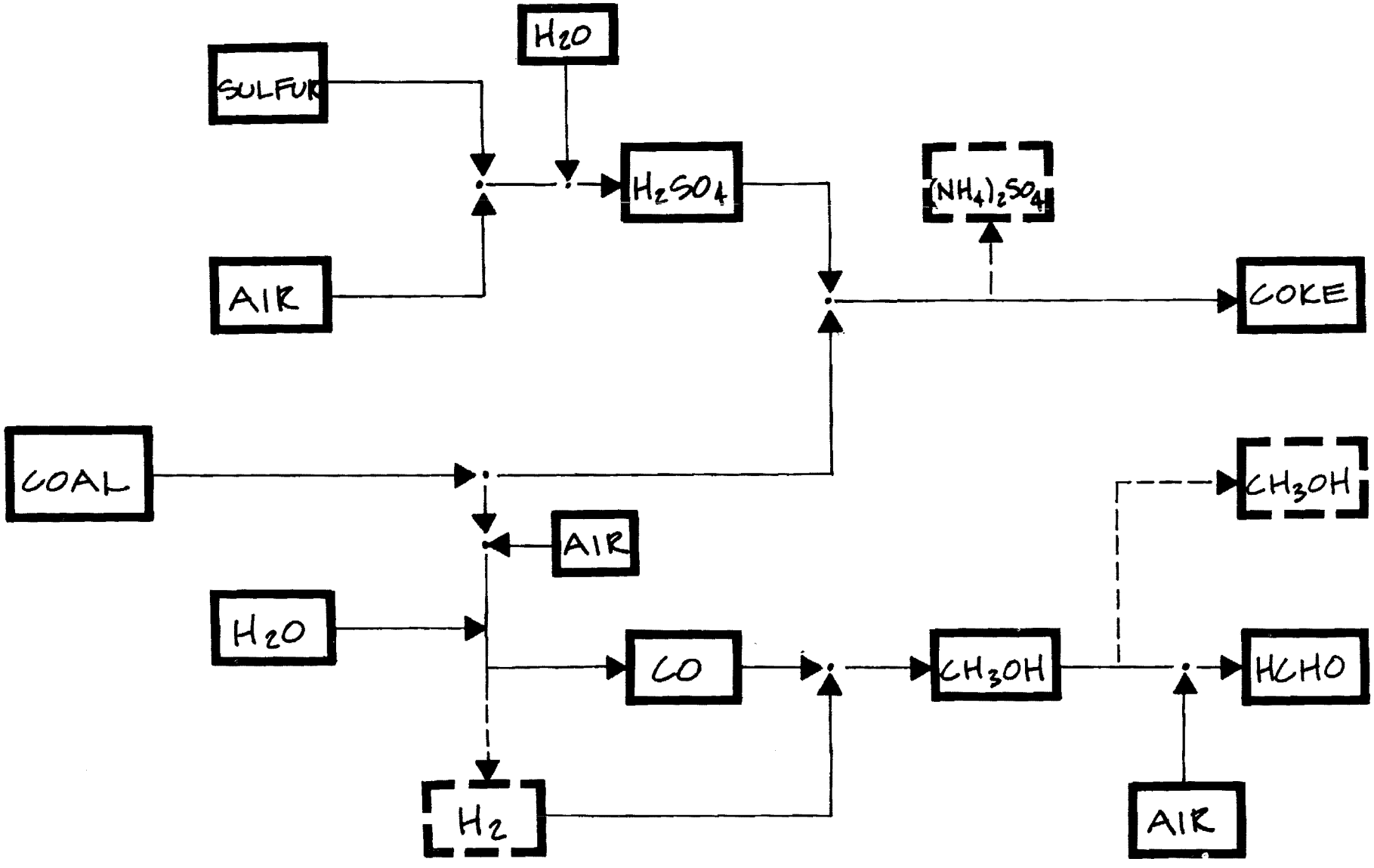


Figure 2-8. First Level of Co-siting of Plants Producing Coal Derivatives, Complex C_5.

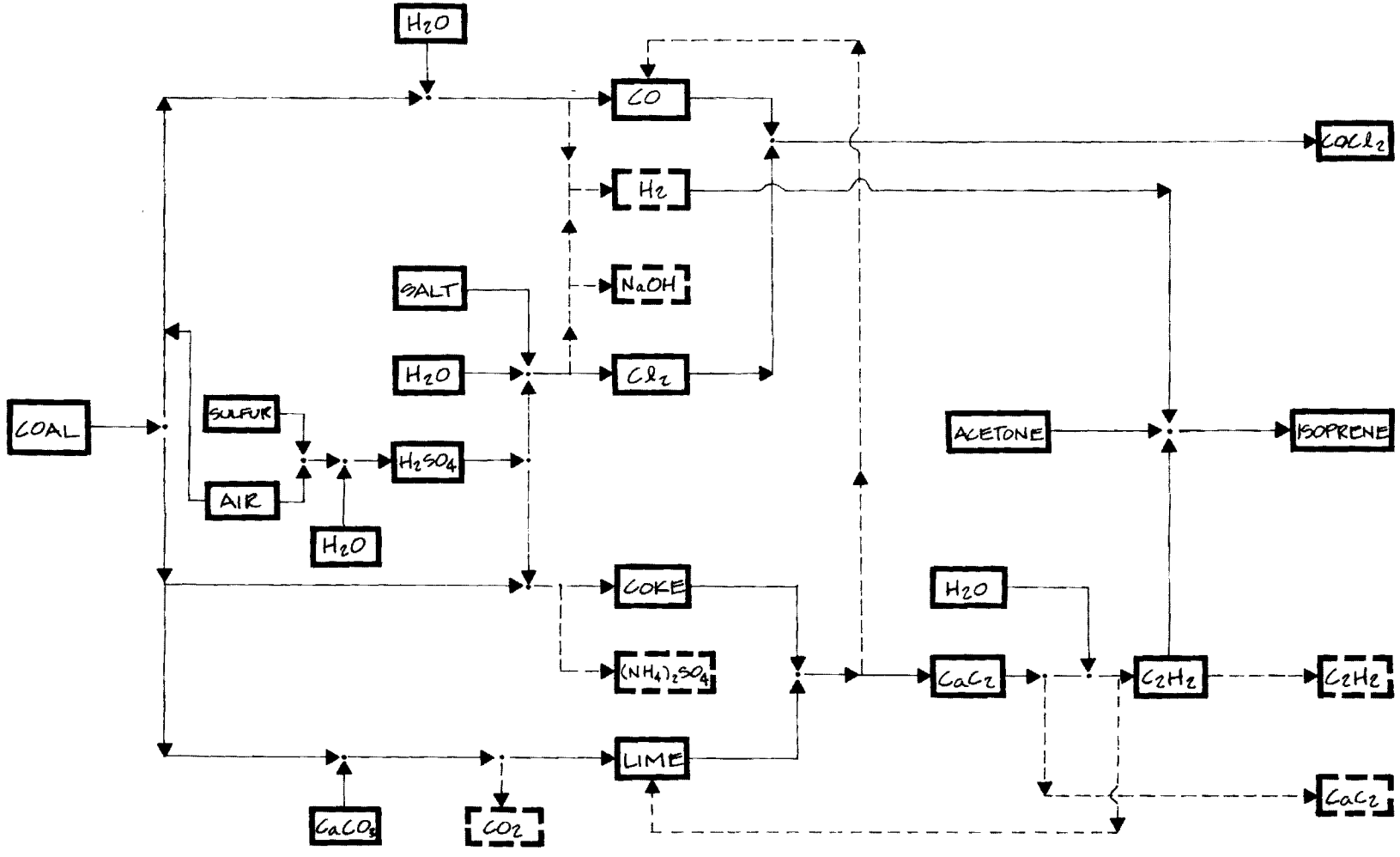


Figure 2-9. First Level of Co-siting of Plants Producing Coal Derivatives, Complex C_6.

TABLE 2-XXIII

Results of Analysis of First Level of Co-siting of Plants Producing Coal Derivatives

PRODUCT	PRODUCTION RATE, tons/yr		CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Coke	1,000,000						
Methanol	300,000	$C_5 \rightarrow$	221.8	112.9	0.7	37.4	37.4
Formaldehyde	150,000						
Calcium carbide	100,000						
Phosgene	50,000	$C_6 \rightarrow$	130.1	147.1	23.5	24.2	124.0
Acetylene	50,000						
Isoprene	40,000						
TOTALS			351.9	260.0	24.2	61.6	161.4

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

such as methanol, calcium carbide and acetylene. There are also small decreases in the by-product credits, raw materials costs and total power requirements resulting from the first co-siting arrangement.

The second level of co-siting (C_{56}) is shown in Figure 2-10; all seven of the coal derivatives are produced in this complex. The results of analysis of this complex are given in Table 2-XXIV. For this second level of co-siting there is a further reduction in the total capital investment from 351.9 to 326.7 million dollars. Further small reductions in the by-product credits, raw material costs and total power requirements are also observed. The reasons for these reductions are essentially the same as those for the similar decreases resulting from the first level of co-siting. Examples of synergistic uses of by-products or co-products here include the usage of by-product carbon monoxide from the calcium carbide plant in the manufacture of methanol and the usage of co-product hydrogen from the chlorine plant (required for the production of phosgene) in the manufacture of methanol and isoprene.

2.7.2 Complexes Based on Salt and Limestone

Another raw material which is abundant in the Appalachian Region is salt (sodium chloride). Limestone (calcium carbonate) is a raw material which is abundant in many regions of the country. Hence, co-sited chemical complexes based upon salt and limestone were also chosen for analysis in this work as examples of regional applications of this methodology.

The results of the search for first-order connections between salt and limestone with the other chemical commodities in the data base are shown in Table 2-XXV. Chlorine is, of course, generally manufactured by electrolysis of aqueous solutions of salt (brine), while sodium metal is obtained by the electrolysis of solid salt. There is only one first-order connection observed with limestone, namely calcium oxide (lime) which is produced by the direct

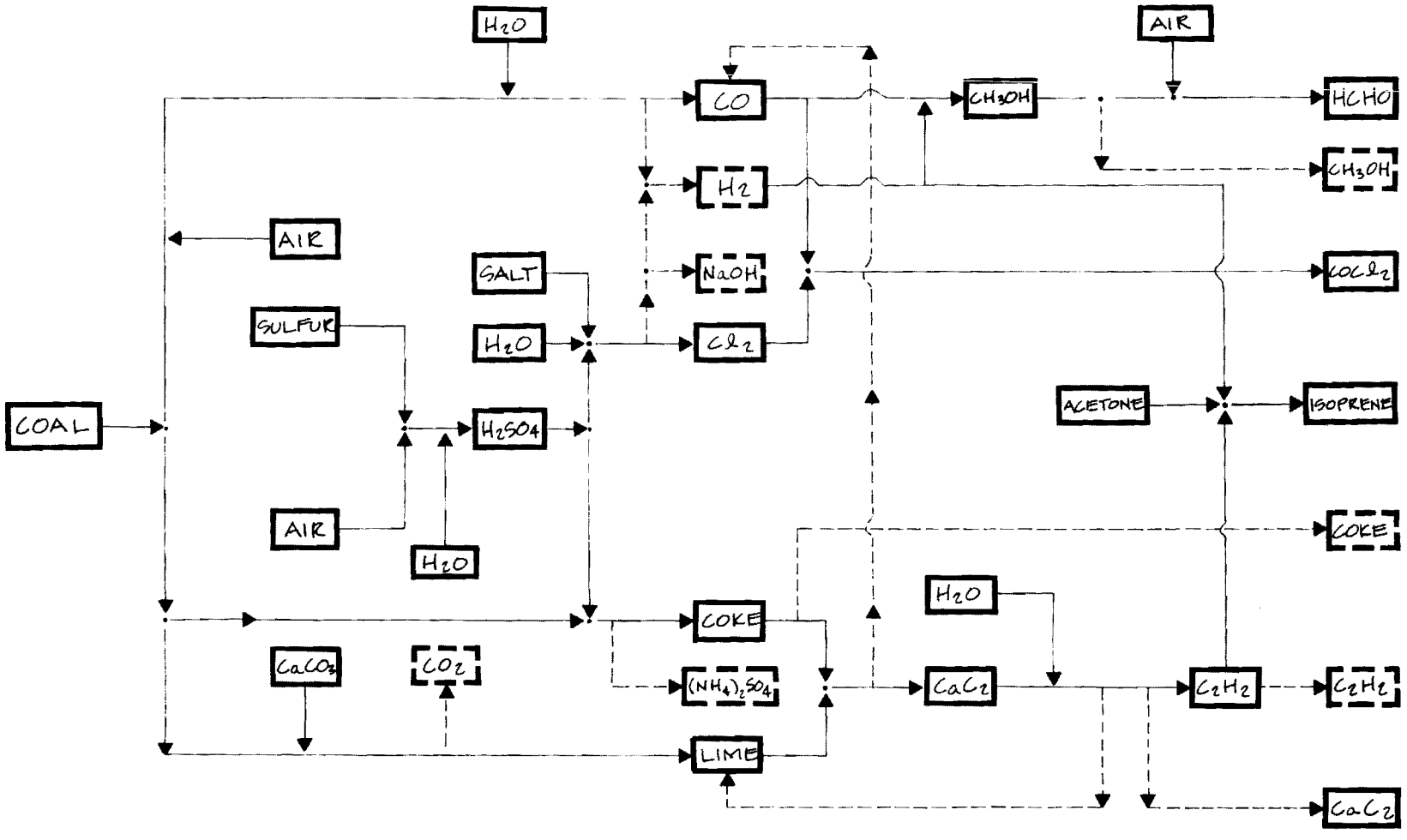


Figure 2-10. Second Level of Co-siting of Plants Producing Coal Derivatives, Complex C_{56}.

TABLE 2-XXIV

Results of Analysis of Second Level of Co-siting of Plants Producing Coal Derivatives (Complex C_{56})

Total capital cost*, MM$	326.7
Total value of products, MM$/yr	260.0
Total by-product credits, MM$/yr	19.0
Total raw material costs, MM$/yr	60.8
Total power requirements, Mw	156.8

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

TABLE 2-XXV

Chemical Commodities with Which Salt and Limestone Exhibit First-Order Connections

Salt	Limestone
Chlorine	Calcium oxide
Ammonium chloride	
Hydrazine	
Sodium chlorate	
Sodium hypochlorite	
Sodium	

calcination of limestone. Vertical expansion of the data base to include additional chemical commodities or allied industries would lead to more first-order connections involving limestone (e.g., cement).

Second-order connections involving salt and limestone are summarized in Table 2-XXVI. The second-order connections of salt with ethylene dichloride and phosgene are obviously through chlorine. Similarly, the second-order connection of limestone and calcium carbide is through lime. The third-order connections exhibited by salt and limestone are given in Table 2-XXVII. Here, the third-order connections of salt with carbon monoxide would be through chlorine and phosgene, while the one with methanol would be through chlorine and hydrogen (a co-product in the electrolysis of brine to manufacture chlorine). The third-order connections of limestone with coke and acetylene are obviously through lime and calcium carbide.

In the analysis of complexes based upon salt and limestone, the following five derivatives of salt were chosen: chlorine, sodium hypochlorite, hydrazine, sodium chlorate and sodium. Similarly, three products derived from limestone were selected -- lime, urea and melamine. As before, merchant production figures for each of these products were first decided upon, and individual or isolated plants for manufacturing these products were then analyzed. The results of these analyses are presented in Table 2-XXVIII. Again, the capital costs, raw material costs and power requirements shown therein for each of the products also include those for all supporting plants (e.g., ammonia required in the production of hydrazine, urea and melamine).

The first level of co-siting then consisted in manufacture of the five salt derivatives in one complex and of the three limestone derivatives in another complex (complexes C_7 and C_8 in Figures 2-11 and 2-12, respectively). The results of analysis of these two complexes are presented in Table 2-XXIX.

TABLE 2-XXVI

Chemical Commodities with Which
Salt and Limestone Exhibit Second-Order Connections

Salt	Limestone
Ammonia	Calcium carbide
Hydrogen chloride	Carbon dioxide
Perchloroethylene	Coal
Caustic soda	
Ammonium sulfate	
Sodium sulfate	
Hydrogen	
Ethylene dichloride	
Sulfuric acid	
Phosgene	

TABLE 2-XXVII

Chemical Commodities with Which
Salt and Limestone Exhibit Third-Order Connections

Salt	Limestone
Ethylene	Carbon monoxide
Methanol	Ethylene oxide
Ammonium nitrate	Maleic anhydride
Nitric acid	Acetylene
Urea	Urea
Vinyl chloride	Melamine
Aniline	Coke
Coke	
Ethyl ether	
Methyl methacrylate	
Isoprene	
Oxygen	
Carbon monoxide	
Acrylonitrile	
Cyclohexane	
Monoethanolamine	
Methyl chloride	
Tetrahydrofuran	
Nitrogen	
Melamine	
Ethyl acrylate	
Ethyl chloride	
Sulfur	

TABLE 2-XXVIII

Results of Analysis of Individual Plants Producing Derivatives of Salt and Limestone

PRODUCT	PRODUCTION RATE, tons/yr	CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Chlorine	350,000	55.7	43.8	153.3	28.7	125.0
Sodium hypochlorite	20,000	14.3	8.0	0.0	0.9	7.3
Hydrazine	5,000	15.5	16.0	0.0	0.4	6.4
Sodium chlorate	20,000	7.6	5.6	0.0	0.6	12.1
Sodium	20,000	11.8	9.0	3.8	2.8	3.6
Lime	800,000	6.0	20.0	12.5	12.4	2.4
Urea	150,000	21.6	24.0	0.0	16.8	6.0
Melamine	20,000	19.8	13.6	0.0	7.4	3.1
TOTALS		152.3	140.0	169.6	70.0	165.9

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

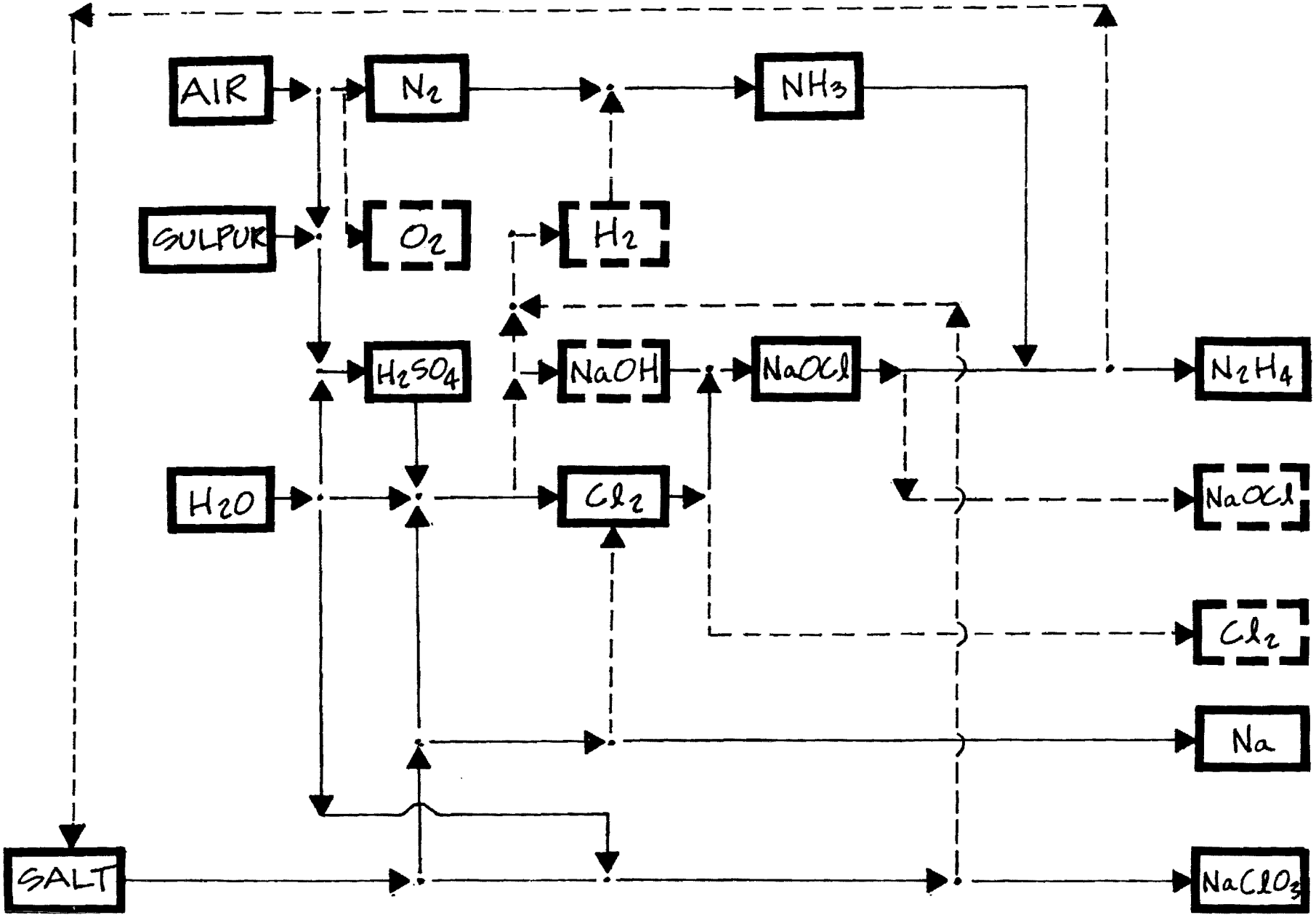


Figure 2-11. First Level of Co-siting of Plants Producing Salt Derivatives, Complex C_7.

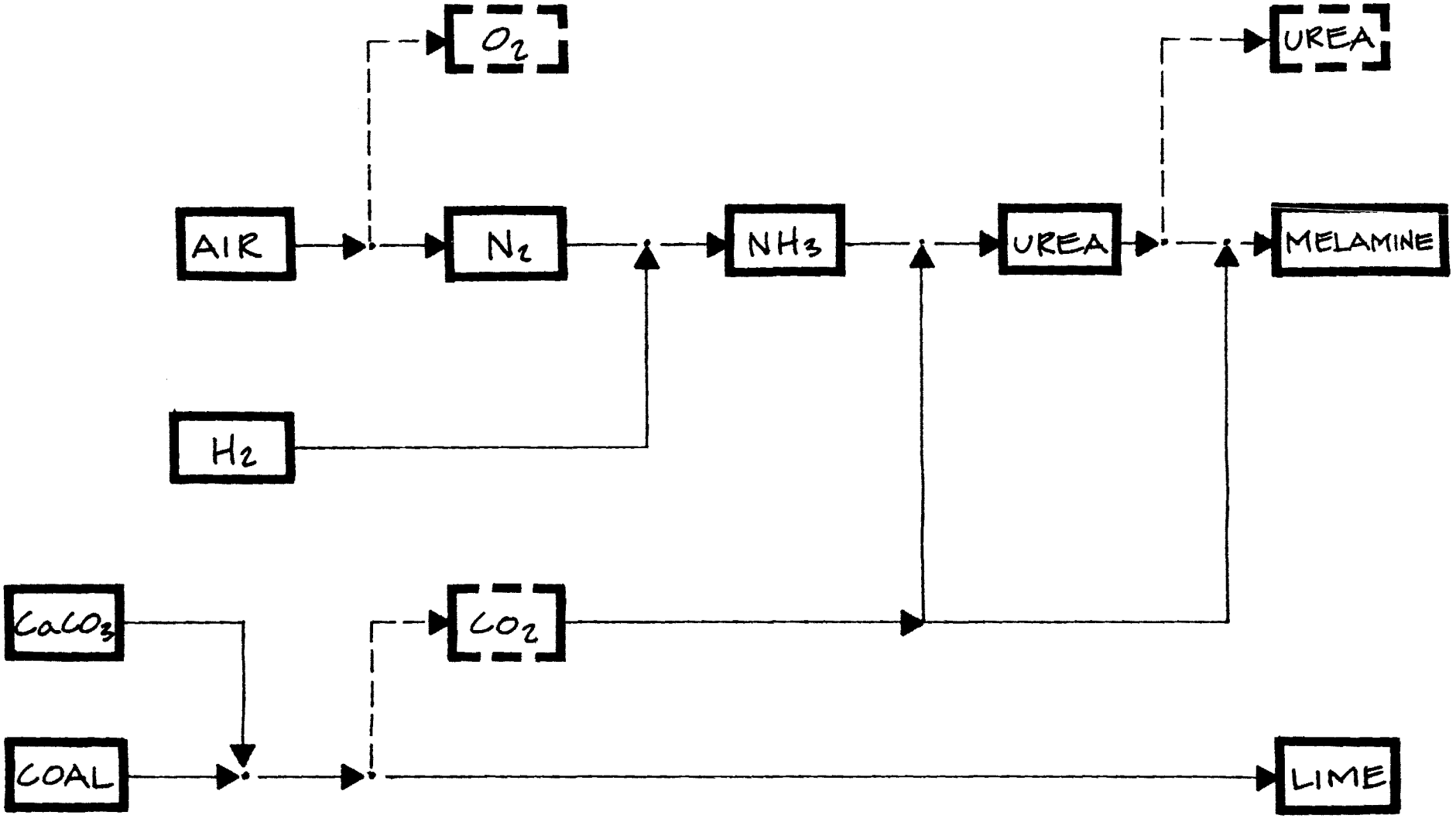


Figure 2-12. First Level of Co-siting of Plants Producing Limestone Derivatives, Complex C_8.

TABLE 2-XXIX

Results of Analysis of First Level of Co-siting of Plants Producing Derivatives of Salt and Limestone

PRODUCT	PRODUCTION RATE, tons/yr		CAPITAL COST*, MM$	PRODUCT VALUE, MM$/yr	BY-PRODUCT CREDIT, MM$/yr	RAW MATERIAL COST, MM$/yr	POWER REQ., megawatts
Chlorine	350,000						
Sodium hypochlorite	20,000						
Hydrazine	5,000	C_7 →	79.9	82.4	140.2	30.9	143.7
Sodium chlorate	20,000						
Sodium	20,000						
Lime	800,000						
Urea	150,000	C_8 →	42.1	57.6	8.7	32.8	11.5
Melamine	20,000						
TOTALS			122.0	140.0	148.9	63.7	155.2

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

Here, the total capital investment reduces from 152.3 to 122.0 million dollars; the primary origins of this reduction are the larger chlorine plant in complex C_7 to produce merchant chlorine and its derivatives and larger ammonia and urea plants in complex C_8. By-product credits, raw material costs and total power requirements are also reduced by 5-10% in this first level of co-siting. These decreases are the result of usage of by-products and co-products in the two complexes, e.g., hydrogen from the chlorine plant to manufacture ammonia, caustic soda (NaOH) from the chlorine plant to produce sodium hypochlorite (NaOCl) and thence hydrazine (N_2H_4), recovery of by-product salt from the hydrazine plant and by-product chlorine from the sodium (Na) plant, and usage of co-product carbon dioxide (CO_2) from the lime plant in the manufacture of urea and melamine.

All of these derivatives of salt and limestone are manufactured in a single complex at the second level of co-siting. The flowsheet for this complex (C_{78}) is shown in Figure 2-13, and the results of analysis of this complex are given in Table 2-XXX. Only slight reductions in the total capital investment, by-product credits, raw material costs and total power requirements are observed at this second level of co-siting. This is not too surprising a result from a cursory inspection of the flowsheet in Figure 2-13; the only intermediate product common to both complexes C_7 and C_8 is ammonia, and the only opportunity for synergistic usage of a co-product here is the utilization of hydrogen from the chlorine plant in the larger ammonia plant.

2.7.3 Complexes Based on Derivatives of Coal, Salt and Limestone

A fully integrated, co-sited complex producing all fifteen (seven coal derivatives, five salt derivatives and three limestone derivatives) chemical products was finally analyzed. The flowsheet for this complex (C_{5678}) is given in Figure 2-14, and the results of analysis of this complex are presented in Table 2-XXXI. Comparing the entries of this table with the sums of the

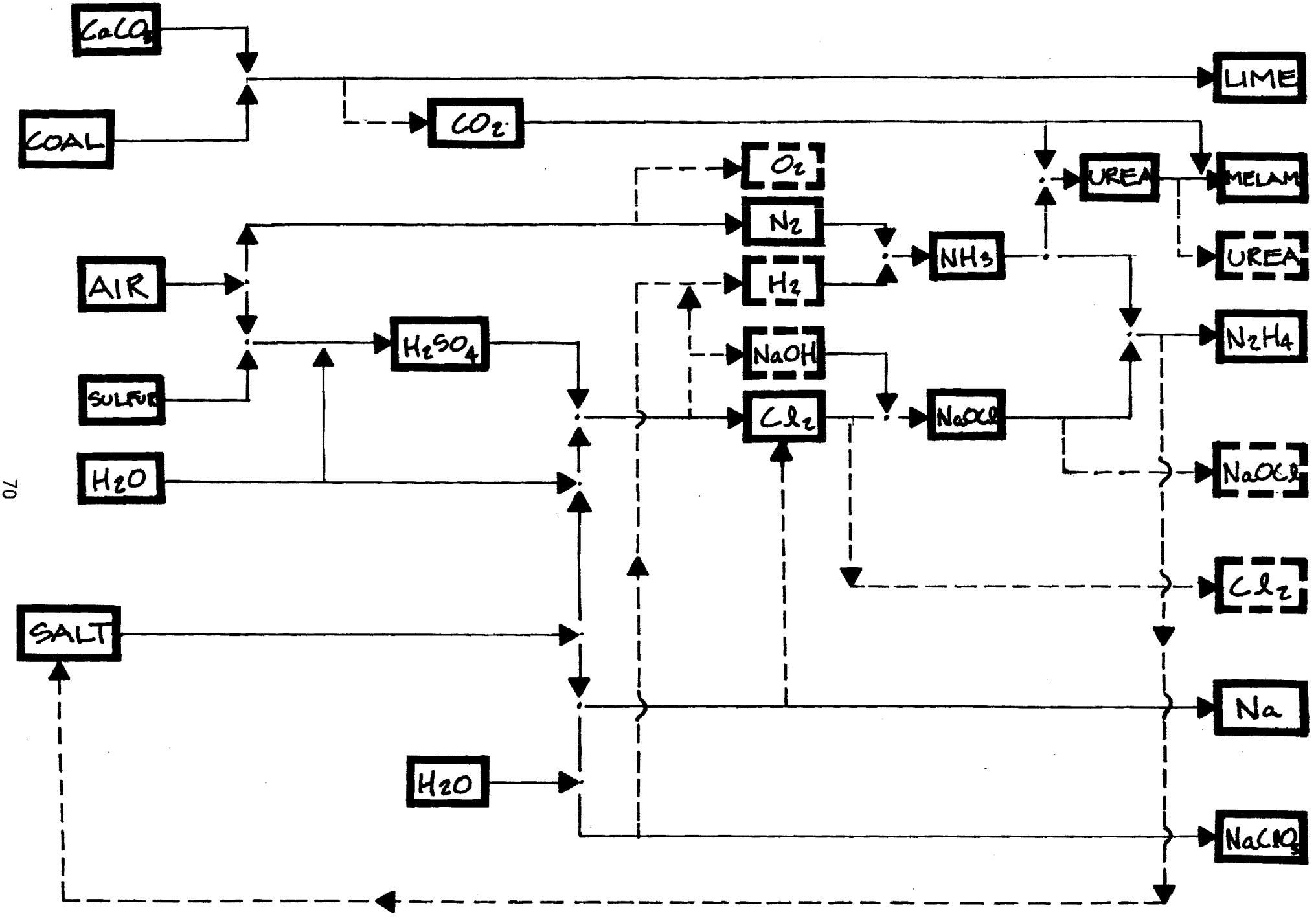


Figure 2-13. Second Level of Co-siting of Plants Producing Derivatives of Salt and Limestone, Complex C_{78}.

TABLE 2-XXX

Results of Analysis of Second Level of Co-siting of Plants Producing Derivatives of Salt and Limestone (Complex C_{78})

Total capital cost*, MM$	121.4
Total value of products, MM$/yr	140.0
Total by-product credits, MM$/yr	148.5
Total raw material costs, MM$/yr	63.3
Total power requirements, Mw	155.1

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

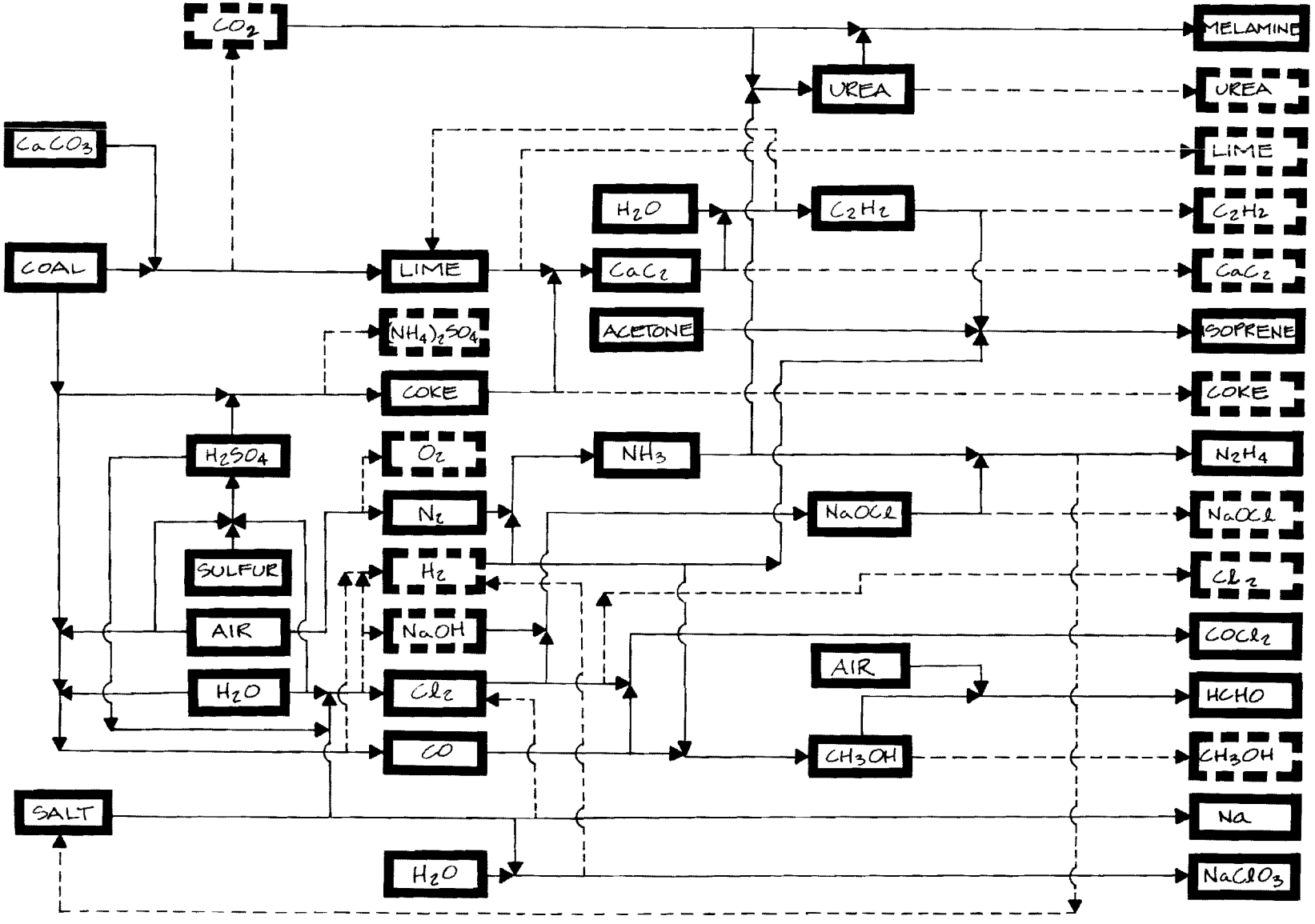


Figure 2-14. Fully Integrated Co-Sited Complex for Producing Derivatives of Coal, Salt and Limestone, Complex C_{5678}

TABLE 2-XXXI

Results of Analysis of a Fully Integrated Co-sited Complex of Plants Producing Derivatives of Coal, Salt and Limestone (Complex C_{5678})

Total capital cost*, MM$	431.8
Total value of products, MM$/yr	400.0
Total by-products, MM$/yr	167.5
Total raw material costs, MM$/yr	124.1
Total power requirements, Mw	311.9

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

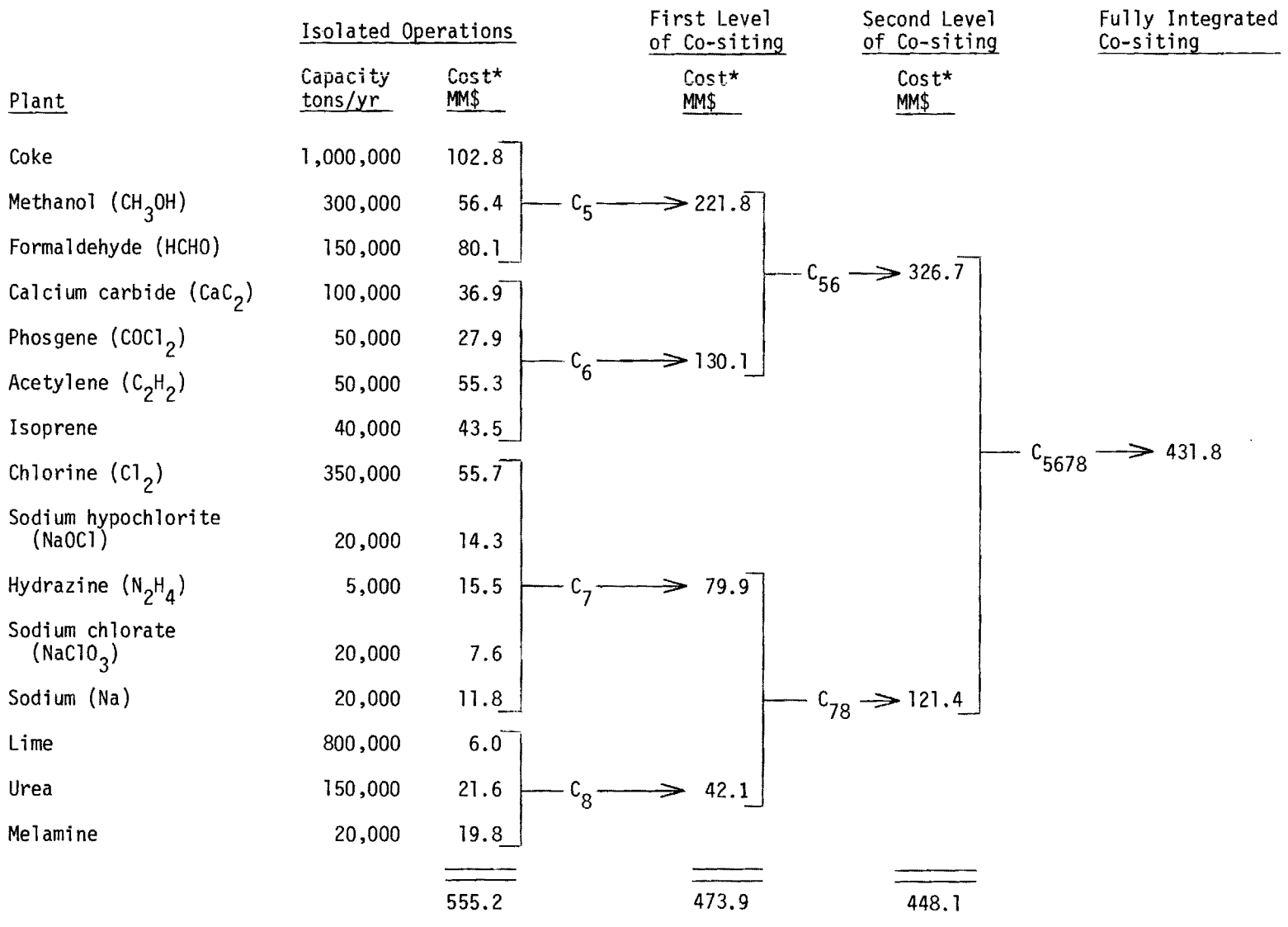
appropriate results from Tables 2-XXIV and 2-XXX, one sees that there is no further synergistic usage of by-products and co-products in this fully integrated complex; that is, there is no reduction in either the total by-product credits, raw material costs or total power requirements. There is, however, a further reduction in the total capital investment required from 448.1 to 431.8 million dollars. This reduction is primarily the result of single larger plants producing lime and chlorine in this fully integrated complex. A summary of the capital investment costs associated with the individual plants and various levels of co-siting of plants for producing the derivatives of coal, salt and limestone is given in Table 2-XXXII.

2.7.4 Regional Impact Factors

In addition to the technical and economic factors which provided the basis for the examples described in Sections 2.7.1 through 2.7.3, some other very important factors combine to affect grouping and siting choices of industrial planners. These include geographical, policy and regulatory, social, legal, market and transportation constraints. Regional analysis studies, such as those by Isard and others[1,3,5,15 and 16], relating to industrial complexing, have characterized many of these factors and generalized their scope of influence in siting decisions. Before complexing options, of the type described earlier in this section, can be finally selected for a region, regional-impact analyses will be necessary to provide adequate consideration of these factors, on a region-specific basis. This step will require extensive cooperative efforts with regional industrial planners. But such a step would be premature until serious in-depth applicational projects have been initiated for specific prototype locations. Therefore, this step was beyond the scope of the present study.

TABLE 2-XXXII

Cost Comparisons Between Individual Plants and Various Co-siting Levels for Producing Derivatives of Coal, Salt and Limestone



* Capital cost only. Not included are offsite facilities, land costs, and utilities.

2.8 Task VIII -- Formulation of Conclusions and Recommendations

This task consisted of reviewing the essential results of the previously discussed tasks, assessing the overall significance of the findings that derived from efforts on these tasks, and compiling these into a set of user-oriented guidelines for the application of the results and methodology developed on this program. These guidelines were developed into (1) a user-interactive computer program and (2) specific conclusions and recommendations. For more effective use of these results, the user-interactive computer program, which facilitates the use of the methodology developed on this program, is presented separately in Section 3. Similarly, the conclusions and recommendations are summarized in Section 4.

2.9 Task IX -- Initiation of Utilization Plan

Efforts on this task involved the communication of the concept of synergistic co-siting and the methodology developed on this program to interested users. Communication was achieved by means of (1) a conference and workshop on synergistic co-siting, (2) a user-interactive computer program, and (3) an application guideline manual.

A conference and workshop was held at Georgia Tech on January 22, 1976, for invited participants consisting of ARC and appropriate State of Georgia staff members, potential industrial and government users, and EES project staff members. The objectives of this meeting were twofold: (1) to introduce the concept of synergistic co-siting to a broadly representative group of potential users of the results of this study in the interest of stimulating the application and implementation of the results and (2) to obtain useful and beneficial feedback for guiding the alignment and orientation of the investigative effort. Mr. Lewis L. Spruill, then the Director of the Georgia

State Energy Office, was the keynote speaker and a total of thirty persons were in attendance. The attendees and their affiliations are listed in Appendix C.

A user-interactive computer program was prepared to facilitate the application of the methodology developed on this program for the selection of co-sited groupings that match the requirements of a community or region. This program, which is described in detail in Section 3.0 of this report, is in the user-conversational, interrogative mode and does not require the user to have detailed knowledge of the internal computational schemes described in Sections 2.1 through 2.6 of this report. Its main purpose is to permit industrial planners to match the characteristics and needs of their areas with co-siting possibilities that would be technically and economically feasible in meeting their requirements.

To simplify the concept of synergistic co-siting and its application for various purposes of interest to potential users, an applications guidelines manual was prepared as a supplement to this final report. These guidelines include the specific steps involved in utilizing the user-interactive computer program and specific examples.

3.0 USER-INTERACTIVE COMPUTER PROGRAM

3.1 General Description

This section summarizes the design and application of a user-interactive computer program that was developed on Task IX to facilitate and encourage the use of the methodology developed on this project for the screening, selection, and economic comparison of co-sited industrial groupings. Specifically, this computer program has been structured to assist industrial planners in matching the characteristics and needs of their areas with technically and economically feasible co-siting possibilities. The program involves an interrogative-conversational format and consists of the following list of questions and guideline statements:

1. HAVE YOU USED THIS PROGRAM BEFORE?
2. DO YOU WANT A DESCRIPTION OF THIS PROGRAM?
3. DO YOU WANT A LIST OF THE 88 INDUSTRIES INCLUDED IN THE DATA BASE OF THIS PROGRAM?
4. DO YOU WANT A LIST OF SOURCES OF DESCRIPTIVE INFORMATION FOR INDUSTRIES IN THE DATA BASE?
5. WOULD YOU LIKE TO PERFORM A SEARCH FOR CO-SITING CANDIDATES FOR A SPECIFIC CORE OF INDUSTRIES?
6. HOW MANY INDUSTRIES CONSTITUTE THE CORE OF THE COMPLEX YOU ARE CONSIDERING? (THE CORE MAY CONSIST OF NEW INDUSTRIES ONLY, EXISTING INDUSTRIES ONLY, OR BOTH NEW AND EXISTING INDUSTRIES.)
7. LIST THE CODES OF THE INDUSTRIES IN THE CORE.
8. AT THIS POINT WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF INDUSTRIES AND BEGIN ANOTHER SEARCH FOR CO-SITING CANDIDATES FOR THIS CORE?
9. WOULD YOU LIKE TO PERFORM AN ECONOMIC ANALYSIS FOR A SPECIFIC COMPLEX?
10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU SPECIFY MERCHANT CAPACITIES?
11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE COMPLEX AND THEIR MERCHANT CAPACITIES, I.E., INDUSTRY NUMBER, CAPACITY (TONS/YEAR).

12. SEVERAL OPTIONS ARE AVAILABLE FOR THE ANNUAL INCREASE IN THE COST OF CHEMICAL PLANTS. INCORPORATED IN THIS COMPUTER PROGRAM, AS OPTION (1), FOR THIS RATE OF INCREASE IS THE AVERAGE MARSHALL-STEVENS INDEX FOR THE YEAR 1975, WITH AN ALLOWANCE FOR AN ANNUAL AVERAGE INCREASE OF 4.5 PERCENT FOR YEARS BEYOND 1975 IN WHICH A PLANT MIGHT BE CONSTRUCTED. OPTION (2) PROVIDES FOR THE SPECIFICATION OF ANY MARSHALL-STEVENS INDEX OF INTEREST. OPTION (3) IS A MODIFICATION OF OPTION (1) WHICH USES THE MARSHALL-STEVENS INDEX INCORPORATED IN THE PROGRAM FOR THE YEAR 1975, BUT PERMITS THE USER TO SPECIFY AN ANNUAL INCREASE OTHER THAN 4.5 PERCENT BEYOND THE 1975 INDEX VALUE.

    TYPE IN THE OPTION YOU PREFER.

13A. TYPE IN THE YEAR OF INTEREST (OPTION 1 ONLY).

13B. TYPE IN THE MARSHALL-STEVENS INDEX OF INTEREST (OPTION 2 ONLY).

13C. TYPE IN THE YEAR OF INTEREST (1975 OR LATER) AND THE ANNUAL PERCENT OF INCREASE (OPTION 3 ONLY), I.E., YEAR, ANNUAL PERCENT.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH A DIFFERENT ANNUAL INCREASE IN PLANT COSTS?

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR ANOTHER COMPLEX?

15B. DO YOU WANT TO USE THE SAME PLANT-COST BASIS IN THIS ANALYSIS YOU CHOSE IN RESPONSE TO STATEMENTS 12 AND 13 IN THE PREVIOUS ANALYSIS?

16. WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF INDUSTRIES AND BEGIN ANOTHER SEARCH FOR CO-SITING CANDIDATES FOR THIS CORE?

As can be seen from the above list, the format utilizes procedural and explanatory steps that are tailored for the experience level of the individual user. Responses selected by the user for each of the questions or guideline statements determine the sequence of further steps in the procedural format. This is demonstrated in the logic diagram for the overall program shown in Figure 3-1.

The overall functions performed for the user by the computer program are accomplished in three major groupings of the 16 statements. These groupings are explained below.

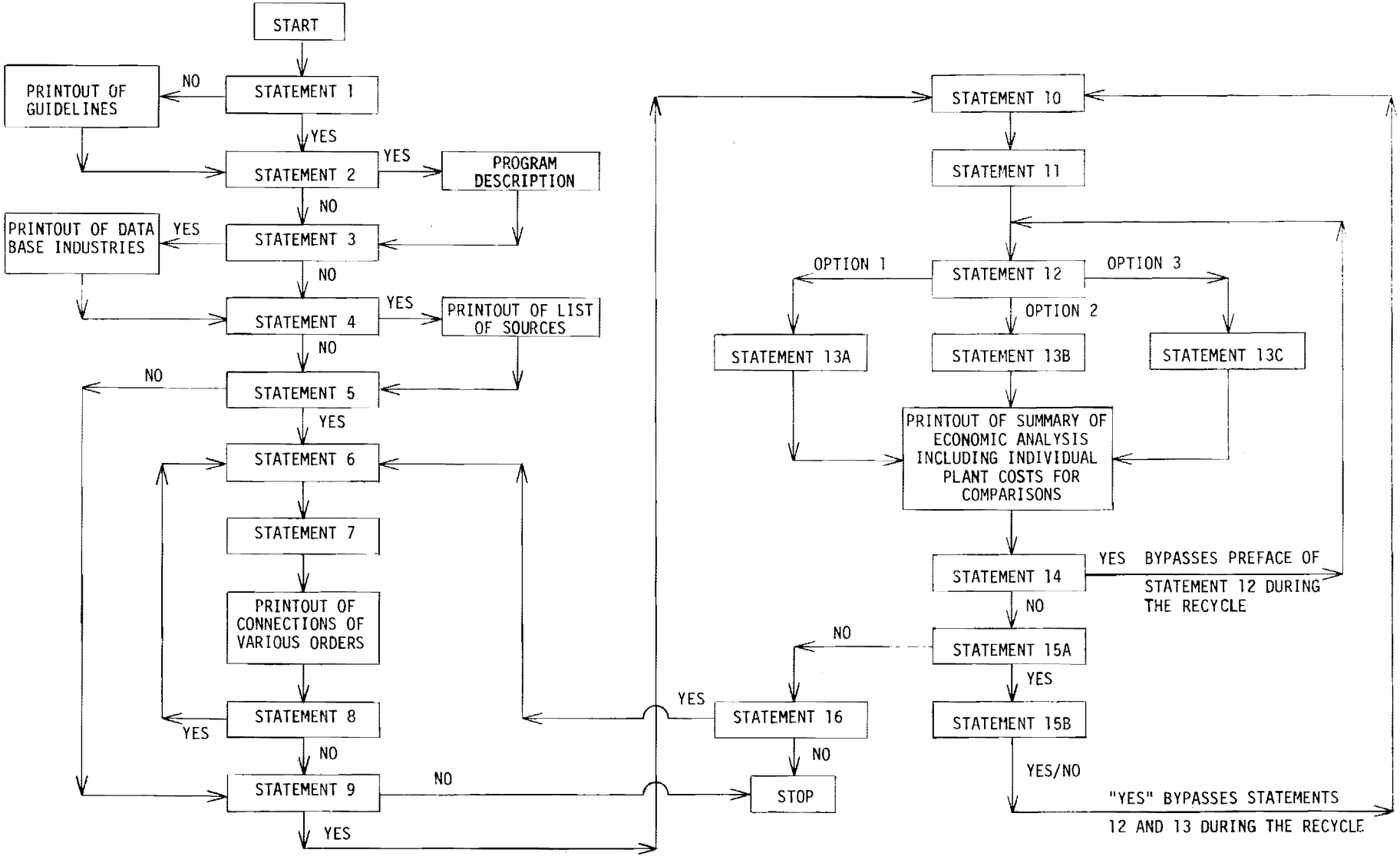


Figure 3-1. Logic Diagram of the User-Interactive Computer Program

GROUP 1 (Statements 1-4): This segment of the program provides the user with background information relating to steps in the program and items in the data base. It is necessary that a new user (i.e., unskilled in the use of the program) request the list of chemicals which are included in the data base of the program in order to obtain the code numbers of chemicals or industries which will be required as input information in response to later statements.

An option is also available for the user to request a list of references which may be consulted for general information on chemical processes.

GROUP 2 (Statements 5-8); This segment of the program searches for co-siting candidates and prints connections of various orders. The user is required to provide a "core" which may consist of one or more than one chemical commodity. For example, an abundance of coal might suggest a coal-based complex and in this case coal alone would constitute the "core." In general, as far as the user is concerned, there are no restrictions regarding chemicals or their number that may comprise the "core," as long as they are listed in the data base.

The printout consists of items listed under the titles "COMPONENT 1" and "COMPONENT 2." The item(s) listed under "COMPONENT 1" are the chemicals which the user provides as the "core." The chemicals under "COMPONENT 2" are the appropriate potential co-siting candidates.

The term "order of connection" can be best explained through an example. Consider the simple production schemes in Figure 3-2 below including only one of the many processes involving coal.

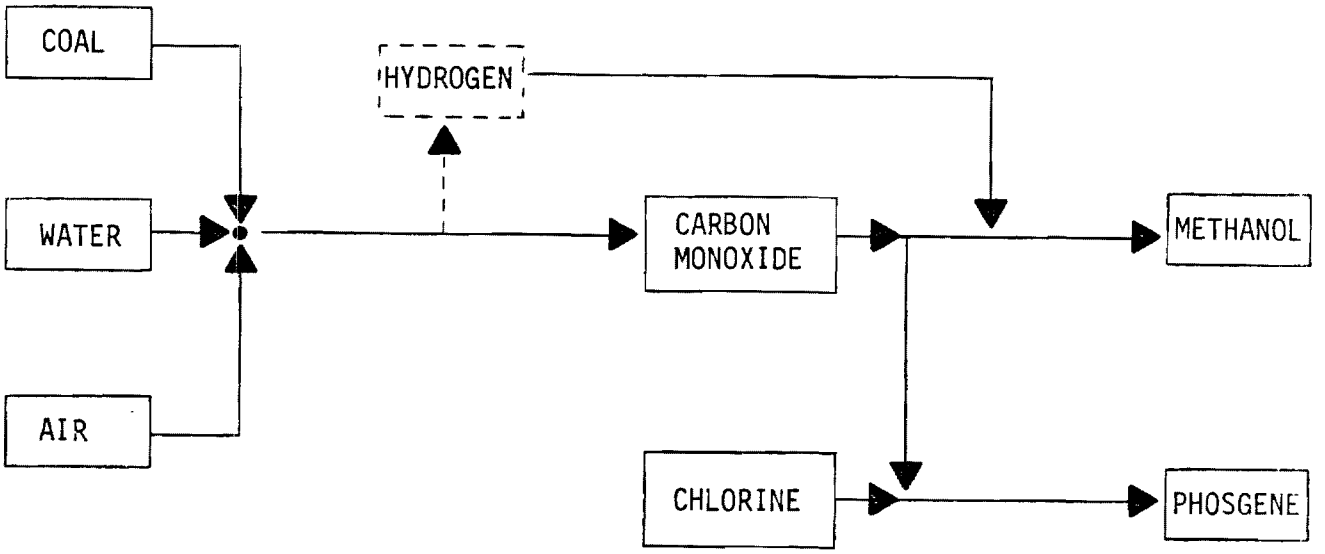


Figure 3-2. Schematic Example of Process Connections.

In the above example, the unique connections are (neglecting air and water as explained below):

first-order (direct coupling) between --

COAL	and	CARBON MONOXIDE
CARBON MONOXIDE	and	METHANOL, HYDROGEN, AND PHOSGENE
HYDROGEN	and	METHANOL
CHLORINE	and	PHOSGENE

second-order (coupling through one intermediate component) between --

COAL	and	METHANOL, HYDROGEN, AND PHOSGENE
CARBON MONOXIDE	and	CHLORINE, HYDROGEN, AND METHANOL
METHANOL	and	HYDROGEN AND PHOSGENE
PHOSGENE	and	HYDROGEN

third-order (coupling through two intermediate components) between --

COAL	and	CHLORINE, HYDROGEN, AND METHANOL
HYDROGEN	and	CHLORINE AND PHOSGENE
METHANOL	and	CHLORINE AND PHOSGENE

fourth-order (coupling through three intermediate components) between --

CHLORINE	and	HYDROGEN AND METHANOL

It would appear from the example schematic diagram (Figure 3-2) that coal and hydrogen should be related by a first-order connection. However, since carbon monoxide was designated to be the principal product of interest from the reaction of coal, air and water, hydrogen was designated as a by-product. In this respect, since the computer program permits only one first-order connection between a product and each of the input materials for a given process, the choice for this connection must be the one relating to the principal product; then the by-products are considered to be second-order connections with the materials that are inputs to the process. Therefore, in this example, coal and hydrogen are shown to be related first by a second-order connection. In turn, the principal product and the by-product(s) of a process are considered to be related by a first-order connection (i.e., the principal product causes the other(s) to be produced without any further chemical reaction steps). In addition, connections for air and water are not shown since both are considered to be cost-free materials and do not appear in the data base. Also, only the lowest connection order for two materials will be shown in the computer printout. For example, in the process-connection scheme shown in Figure 3-2, although carbon monoxide and hydrogen are connected both by first-order (principal product to by-product) and second-order (through methanol) relationships, only the first-order connection would be shown in the computer printout. Similarly, only the lowest-order connections for the other components would be printed out.

GROUP III (Statements 9-16): This segment deals with the economic analysis for a chosen complex. Following is an explanation of the terms and abbreviations which appear in the printout of the economic analysis:

CAPTIVE PRODUCTION - Production of a chemical which is consumed within the complex itself. A negative value indicates generation of a by-product.

MERCHANT PRODUCTION - Production which will be shipped to markets outside the complex (i.e., external).

TOTAL PRODUCTION - Sum of captive and merchant productions.

REMARKS - Displays the role of certain chemicals either as by-products or as raw materials for the convenience of the user. In the case of ethylene glycol, "NO DATA" will appear under this column; plant costs for this chemical are included in those for ethylene oxide from which it is derived.

PLANT COST - Costs shown are capital costs only. Not included are offsite facilities, land costs, and utilities.

PRODUCT VALUE - Product market values are computed and displayed for items which have a non-zero merchant production.

RAW MATERIAL COST - Market value of raw materials consumed in the complex.

BY-PRODUCT CREDIT - Credit value associated with the generation of by-products which are shipped outside the complex.

POWER - Power consumed for the total production of a chemical. Shown for only those items with which a plant cost is associated.

TPY - Tons/year.

MM$ - Millions of dollars

MM$PY - Millions of dollars per year.

MW - Megawatts.

The list of 88 "industries" in the data base, which the computer program will provide if so instructed in Statement 3, includes six basic raw materials identified by ** and twenty-one by-product materials identified by * (a print-out of these "industries" is shown in Section 3.2.2). Due to the roles of these

materials in the various processing schemes considered in the methodology, merchant capacities should not be specified for any of these materials in response to Statement 11. However, any of these materials may be considered as core industries in response to Statement 7.

It should also be noted that neither air nor water is listed in the data base since they were assumed to be available at no cost. However, they were included where required in the computational procedures and are shown on flowsheets presented in this report.

3.2 Illustrative Example

3.2.1 Description and Discussion

The essential features and applicational significance of this user-interactive program can best be characterized by the following illustrative example. The example case involves the identification and economic comparison, for the year 1975 based on the Marshall-Stevens Index, of feasible co-siting groupings for the use of a locally available supply of coal. This will demonstrate the use of the interactive computer procedure in accomplishing an example regional applicational analysis described earlier in Section 2.7.1.

The computer printout for this illustrative example is provided in Section 3.2.2 and has the statement format described earlier in Section 3.1. Guidelines for and responses to the various computer statements are as follows:

- Statements 1-5. The first 5 statements of the format are straightforward and prepare the user, based on his background, for the computer procedure. For illustrative purposes, the responses were: -- "no," "yes," "yes," "yes," and "yes," respectively.
- Statement 6. Since in this example, only one industry (coal) constituted the core, the response was "1."
- Statement 7. From the data-base printout of Statement 3, the code for

coal is 59, and the response was therefore "59." The computer output at this point consists of listings of the various connection orders appropriate to coal as a starting (core) material. In general, the search results obtained from Statement 7 provide the user with a basis for selecting one or more complexes for economic analysis and comparison through the procedure options that begin with Statement 9. In this example, several of the products identified by the search routine were of interest based upon locally important features (e.g., local markets, existing plants, etc.). These products are coke, methanol, formaldehyde, calcium carbide, phosgene, acetylene, and isoprene. At this point, merchant capacities in tons/year for each of these were determined for use in the economic analyses. The first levels of co-siting involved two separate complexes, one based upon a combination of coke, methanol, and formaldehyde only (designated as Complex C_5 in Figure 2-8), and a second based upon a combination of calcium carbide, phosgene, acetylene, and isoprene only (designated as Complex C_6 in Figure 2-9). The final level of co-siting was a complete complex (designated as Complex C_{56} in Figure 2-10) that combined the two first-level complexes and produced all seven of the coal derivatives. Economic analyses were performed separately for each of these complexes in this example.

Statement 8. The response was "no" since no other core was of interest at this point. If another core (such as coal with limestone and salt as analyzed in Section 2.7.3 of this report) had been of interest, it could have been designated at this point and another search for co-siting candidates would have been made. Further, if the search

based on coal had provided no candidates, a search for another core choice could have been made.

● Statement 9. The response was "yes," and Complex C_5 was the basis for the first economic analysis which begins with the response to Statement 10.

● Statement 10. Since there are three industries (coke, methanol, and formaldehyde) having merchant capacities in Complex C_5, the response was "3."

● Statement 11. The response was "70," "1000000"; "3," "300000"; "27," "150000." The respective code numbers were obtained from the data-base printout of Statement 3, and the merchant capacities are those selected to be relevant for these products as discussed under Statement 7 above.

● Statement 12. Since this illustrative example specified economic comparisons based on the Marshall-Stevens Index, the response was "1." Note that as pointed out in the computer printout for Statement 12, the user has two other options available to him.

● Statement 13A. Since the year specified in this illustrative example for the Marshall-Stevens Index was 1975, the response was "1975." At this point, economic analyses were printed by the computer for the isolated operations (when not co-sited) for comparison purposes and for the co-sited operations(Complex C_5). It should be noted that the capital costs, power requirements, etc., associated with each of the isolated operations shown in the economic analyses include all of the supporting plants as well (e.g., sulfuric acid plant, carbon monoxide plant, methanol plant, etc., as needed).

● Statement 14. Not desiring at this point to use any other basis for estimating plant costs, the response was "no."

● Statement 15A. Desiring now to analyze Complex C_6, the response was "yes."

● Statement 15B. Desiring to use the same plant-cost basis previously used, the response was "yes."

This response recycled the procedure back to Statement 10 and appropriate information was then provided to the computer by the user for Complex C_6 in response to Statements 10, 11, and 14. Complex C_{56} was then analyzed by a repeat of this procedure.

● Statement 16. Having completed the desired analyses, the response was "no." This response automatically terminates the computer procedure.

The results of this entire example procedure permit the user to compare the relative cost benefits associated with the various levels of co-siting. Capital cost comparisons are summarized in Table 3-I.

Table 3-I. Capital Cost Comparisons Between Isolated Operations and Various Co-Siting Levels

Product	Isolated Operations		First Level of Co-Siting	Second Level of Co-Siting
	Capacity (tons/yr)	Cost* (MM$)	Cost* (MM$)	Cost* (MM$)
Coke	1,000,000	102.8		
Methanol	300,000	56.4	C_5 → 221.8	
Formaldehyde	150,000	80.1		
Calcium Carbide	100,000	36.9		C_{56} → 326.7
Phosgene	50,000	27.9	C_6 → 130.1	
Acetylene	50,000	55.3		
Isoprene	40,000	43.5		
		402.9	351.9	326.7

* Capital cost only. Not included are offsite facilities, land costs, and utilities.

Section 3.2.2 Computer Printout for Illustrative Example

```
 THIS PROGRAM WAS DESIGNED AND COMPUTERIZED DURING
1976 AS PART OF A STUDY INVESTIGATING SYNERGISTIC
CO-SITING CONDUCTED BY THE ENGINEERING EXPERIMENT
STATION OF THE GEORGIA INSTITUTE OF TECHNOLOGY UNDER
CONTRACT TO THE APPALACHIAN REGIONAL COMMISSION,
WASHINGTON, D.C.

1. HAVE YOU USED THIS PROGRAM BEFORE ?
? NO

 SINCE THIS IS THE FIRST TIME YOU HAVE USED THIS
PROGRAM, IT IS RECOMMENDED THAT YOU PROCEED AS
FOLLOWS :

 (1) READ THE "GUIDELINES FOR SYNERGISTIC CO-SITING"
THAT HAS BEEN PREPARED AS A USER MANUAL FOR THIS
PROGRAM TO ACQUAINT YOU WITH ITS PURPOSE AND
PROCEDURAL GUIDELINES. THIS WILL CLARIFY THE STATE-
MENTS WHICH FOLLOW AND PROVIDE A BASIS FOR SELECTING
APPROPRIATE RESPONSES TO THESE STATEMENTS.

 (2) TYPE "YES" IN RESPONSE TO BOTH STATEMENTS 2 AND
3, WHICH FOLLOW. THE COMPUTER WILL THEN PROVIDE YOU
WITH A BRIEF REVIEW OF ESSENTIAL INFORMATION ABOUT
THE COMPUTER PROGRAM AND A LIST OF DATA BASE
INDUSTRIES AND RAW MATERIALS, WITH THEIR CODE
NUMBERS, FROM WHICH YOU MUST SELECT "CORE"
COMPONENTS OF CO-SITING GROUPINGS IN RESPONSE TO
SEVERAL OF THE STATEMENTS THAT FOLLOW. ALWAYS USE
THE APPROPRIATE CODE NUMBER FOR ITEMS OF INTEREST ON
THIS LIST WHEN RESPONDING TO SUCH STATEMENTS.
INDUSTRIES OR MATERIALS THAT ARE NOT ON THIS LIST
CANNOT NOW BE CONSIDERED AS POTENTIAL CANDIDATE
COMPONENTS OF CO-SITING GROUPINGS IN THE ANALYSIS
WHICH THIS PROGRAM ACCOMPLISHES.

2. DO YOU WANT A DESCRIPTION OF THIS PROGRAM ?
? YES
```

THIS PROGRAM INVOLVES AN INTERROGATIVE-CONVERSATIONAL FORMAT WHICH UTILIZES PROCEDURAL AND EXPLANATORY STEPS THAT ARE TAILORED FOR THE EXPERIENCE LEVEL OF THE INDIVIDUAL USER. RESPONSES SELECTED BY THE USER FOR EACH OF THE QUESTIONS OR GUIDELINE STATEMENTS DETERMINE THE SEQUENCE OF FURTHER STEPS IN THE PROCEDURAL FORMAT.

THE OVERALL FUNCTIONS PERFORMED FOR THE USER BY THE PROGRAM ARE ACCOMPLISHED IN THREE MAJOR GROUPINGS OF 16 STATEMENTS :

GROUP 1 (STATEMENTS 1-4) PROVIDES THE USER WITH BACKGROUND INFORMATION RELATING TO STEPS IN THE PROGRAM AND ITEMS IN THE DATA BASE.

GROUP 2 (STATEMENTS 5-8) PROVIDES FOR A SEARCH FOR CO-SITING CANDIDATES AND PRINTS CONNECTIONS OF VARIOUS ORDERS. THE USER IS REQUIRED TO PROVIDE A "CORE" WHICH MAY CONSIST OF ONE OR MORE OF THE CHEMICAL COMMODITIES LISTED IN THE DATA BASE. THE PRINTOUT CONSISTS OF ITEMS LISTED UNDER "COMPONENT 1" (THE CORE ITEMS SPECIFIED BY THE USER) AND "COMPONENT 2" (ITEMS THAT MATCH WITH THE CORE ITEMS AND WOULD BE APPROPRIATE POTENTIAL CO-SITING CANDIDATES.)

GROUP 3 (STATEMENTS 9-16) PROVIDES FOR ECONOMIC ANALYSIS OF CO-SITING GROUPINGS (COMPLEXES) SELECTED BY THE USER FROM THE CANDIDATES IDENTIFIED BY THE GROUP 2 PROCEDURE.

ABBREVIATIONS USED IN THE COMPUTER PRINTOUT, AND THEIR MEANINGS, ARE AS FOLLOWS :

TPY	= TONS PER YEAR
MM$	= MILLIONS OF DOLLARS
MM$PY	= MILLIONS OF DOLLARS PER YEAR
MW	= MEGAWATTS (OF POWER CONSUMED)

FOR A THOROUGH EXPLANATION OF THE TERMS "ORDER OF CONNECTION" AND "CORE", USED IN GROUP 2 STATEMENTS AND PRINTOUTS, AND "MERCHANT CAPACITIES", "CAPTIVE PRODUCTION", "MERCHANT PRODUCTION", "TOTAL PRODUCTION", "PLANT COST", "PRODUCT VALUE", "RAW MATERIAL COST", "BY-PRODUCT CREDIT", "POWER", AND "REMARKS", USED IN GROUP 3 STATEMENTS AND PRINTOUTS, REFER TO "GUIDELINES FOR SYNERGISTIC CO-SITING" THAT HAS BEEN PREPARED AS A USER MANUAL FOR THIS PROGRAM.

3. DO YOU WANT A LIST OF THE 88 INDUSTRIES
   INCLUDED IN THE DATA BASE OF THIS PROGRAM ?
? YES

NO.	INDUSTRY NAME	NO.	INDUSTRY NAME
1	ETHYLENE	2	OXYGEN
3	METHANOL	4	CARBON MONOXIDE
* 5	PROPYLENE	6	AMMONIA
7	CHLORINE	8	BENZENE
* 9	HYDROGEN	* 10	HYDROGEN CHLORIDE
11	ACETALDEHYDE	12	ACETIC ACID
13	ACRYLONITRILE	* 14	ACETONITRILE
* 15	HYDROGEN CYANIDE	16	AMMONIUM NITRATE
17	CUMENE	18	PHENOL
* 19	ACETONE	20	BIS-PHENOL A
21	CYCLOHEXANE	22	ETHANOL
23	ETHYLENE OXIDE	24	MONO-ETHANOL AMINE
25	ETHYLBENZENE	26	ETHYL ACETATE
27	FORMALDEHYDE	28	ISOPROPANOL
29	MALEIC ANHYDRIDE	30	METHYL CHLORIDE
31	NITRIC ACID	32	ETHYLENE DICHLORID
33	PERCHLOROETHYLENE	34	PERACETIC ACID
35	POLYETHYLENE	* 36	BTX FRACTION
* 37	TOLUENE	38	POLYPROPYLENE
39	ETHYLENE GLYCOL	40	STYRENE
41	POLYSTYRENE	42	PROPYLENE OXIDE
43	TETRAHYDROFURAN	* 44	CARBON DIOXIDE
45	UREA	46	VINYL ACETATE
47	VINYL CHLORIDE	48	POLYVINYL CHLORIDE
** 49	ETHANE	** 50	PROPANE
51	ISOPRENE	* 52	NITROGEN
* 53	SODIUM CHLORIDE	* 54	SODIUM HYDROXIDE
* 55	O-XYLENE	* 56	M-XYLENE
* 57	P-XYLENE	** 58	CALCIUM CARBONATE
** 59	COAL	60	ANILINE
61	PHTHALIC ANHYDRIDE	62	TEREPHTHALIC ACID
63	SULFURIC ACID	64	SODIUM CHLORATE
65	MELAMINE	66	ACETIC ANHYDRIDE
67	ACETYLENE	68	CALCIUM CARBIDE
69	CALCIUM OXIDE	70	COKE
* 71	TRICHLOROETHYLENE	* 72	AMMONIUM SULFATE
73	AMMONIUM CHLORIDE	74	NITROBENZENE
75	BENZOIC ACID	* 76	BUTADIENE
77	ETHYL ETHER	78	ETHYL CHLORIDE
79	SODIUM HYPOCHLORIT	80	HYDRAZINE
81	METHYL METHACRYLAT	** 82	SULFUR
83	PHOSGENE	84	SODIUM
* 85	SODIUM SULFATE	* 86	ISO-BUTANE
* 87	TERT-BUTYL ALCOHOL	** 88	SODIUM CARBONATE

* BY-PRODUCTS ONLY
** RAW MATERIALS ONLY

4. DO YOU WANT A LIST OF SOURCES OF DESCRIPTIVE
   INFORMATION FOR INDUSTRIES IN THE DATA BASE ?
? YES

(A) F. A. LOWENHEIM AND M. K. MORAN, "FAITH, KEYES AND CLARK'S INDUSTRIAL CHEMICALS", 4TH EDITION, WILEY, NEW YORK (1975)

(B) R. N. SHREVE, "CHEMICAL PROCESS INDUSTRIES" 3RD EDITION, MCGRAW HILL, NEW YORK (1967)

(C) "CHEMICAL ORIGINS AND MARKETS", STANFORD RESEARCH INSTITUTE (1967)

(D) J. A. KENT, "RIEGEL'S HANDBOOK OF INDUSTRIAL CHEMISTRY", 7TH EDITION, VAN NOSTRAND, NEW YORK (1974)

5. WOULD YOU LIKE TO PERFORM A SEARCH FOR CO-SITING CANDIDATES FOR A SPECIFIC CORE OF INDUSTRIES ?
? YES

6. HOW MANY INDUSTRIES CONSTITUTE THE CORE OF THE COMPLEX YOU ARE CONSIDERING ? (THE CORE MAY CONSIST OF NEW INDUSTRIES ONLY, EXISTING INDUSTRIES ONLY, OR BOTH NEW AND EXISTING INDUSTRIES.)
? 1

7. LIST THE CODES OF THE INDUSTRIES IN THE CORE
? 59

SUMMARY OF CONNECTIONS OF ORDER 1

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	CARBON MONOXIDE	COAL	CALCIUM OXIDE
COAL	COKE		

SUMMARY OF CONNECTIONS OF ORDER 2

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	METHANOL	COAL	HYDROGEN
COAL	CARBON DIOXIDE	COAL	CALCIUM CARBONATE
COAL	SULFURIC ACID	COAL	ACETYLENE
COAL	CALCIUM CARBIDE	COAL	AMMONIUM SULFATE
COAL	PHOSGENE		

SUMMARY OF CONNECTIONS OF ORDER 3

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	AMMONIA	COAL	CHLORINE
COAL	CYCLOHEXANE	COAL	ETHYLENE OXIDE
COAL	FORMALDEHYDE	COAL	MALEIC ANHYDRIDE
COAL	METHYL CHLORIDE	COAL	TETRAHYDROFURAN
COAL	UREA	COAL	ISOPRENE
COAL	SODIUM CHLORATE	COAL	MELAMINE
COAL	AMMONIUM CHLORIDE	COAL	ETHYL ETHER
COAL	METHYL METHACRYLAT	COAL	SULFUR

SUMMARY OF CONNECTIONS OF ORDER 4

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	ETHYLENE	COAL	OXYGEN
COAL	BENZENE	COAL	HYDROGEN CHLORIDE
COAL	ACRYLONITRILE	COAL	HYDROGEN CYANIDE
COAL	AMMONIUM NITRATE	COAL	ACETONE
COAL	ETHANOL	COAL	MONO-ETHANOL AMINE
COAL	NITRIC ACID	COAL	ETHYLENE DICHLORID
COAL	PERCHLOROETHYLENE	COAL	ETHYLENE GLYCOL
COAL	NITROGEN	COAL	SODIUM CHLORIDE
COAL	SODIUM HYDROXIDE	COAL	ANILINE
COAL	SODIUM HYPOCHLORIT	COAL	HYDRAZINE
COAL	SODIUM	COAL	SODIUM SULFATE

SUMMARY OF CONNECTIONS OF ORDER 5

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	PROPYLENE	COAL	ACETALDEHYDE
COAL	ACETONITRILE	COAL	CUMENE
COAL	PHENOL	COAL	BIS-PHENOL A
COAL	ETHYLBENZENE	COAL	ETHYL ACETATE
COAL	PERACETIC ACID	COAL	POLYETHYLENE
COAL	BTX FRACTION	COAL	TOLUENE
COAL	STYRENE	COAL	PROPYLENE OXIDE
COAL	VINYL ACETATE	COAL	VINYL CHLORIDE
COAL	ETHANE	COAL	PROPANE
COAL	O-XYLENE	COAL	M-XYLENE
COAL	P-XYLENE	COAL	TRICHLOROETHYLENE
COAL	NITROBENZENE	COAL	BUTADIENE
COAL	ETHYL CHLORIDE	COAL	ISO-BUTANE

SUMMARY OF CONNECTIONS OF ORDER 6

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	ACETIC ACID	COAL	ISOPROPANOL
COAL	POLYPROPYLENE	COAL	POLYSTYRENE
COAL	POLYVINYL CHLORIDE	COAL	PHTHALIC ANHYDRIDE
COAL	TEREPHTHALIC ACID	COAL	BENZOIC ACID
COAL	TERT-BUTYL ALCOHOL	COAL	SODIUM CARBONATE

SUMMARY OF CONNECTIONS OF ORDER 7

COMPONENT 1	COMPONENT 2	COMPONENT 1	COMPONENT 2
COAL	ACETIC ANHYDRIDE		

CONNECTIONS OF HIGHER ORDERS ARE NOT UNIQUE

8. AT THIS POINT WOULD YOU LIKE TO SPECIFY ANOTHER
   CORE OF INDUSTRIES AND BEGIN ANOTHER SEARCH FOR
   CO-SITING CANDIDATES FOR THIS CORE ?
? NO

9. WOULD YOU LIKE TO PERFORM AN ECONOMIC ANALYSIS
   FOR A SPECIFIC COMPLEX ?
? YES

10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU
    SPECIFY MERCHANT CAPACITIES ?
? 3

11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE
    COMPLEX AND THEIR MERCHANT CAPACITIES, I.E.,
    INDUSTRY NUMBER, CAPACITY (TONS/YEAR)
? 70,1000000
? 3, 300000
? 27, 150000

12. SEVERAL OPTIONS ARE AVAILABLE FOR THE ANNUAL INCREASE IN THE COST OF CHEMICAL PLANTS. INCORPORATED IN THIS COMPUTER PROGRAM, AS OPTION (1), FOR THIS RATE OF INCREASE IS THE AVERAGE MARSHALL-STEVENS INDEX FOR THE YEAR 1975, WITH AN ALLOWANCE FOR AN ANNUAL AVERAGE INCREASE OF 4.5 PERCENT FOR YEARS BEYOND 1975 IN WHICH A PLANT MIGHT BE CONSTRUCTED. OPTION (2) PROVIDES FOR THE SPECIFICATION OF ANY MARSHALL-STEVENS INDEX OF INTEREST. OPTION (3) IS A MODIFICATION OF OPTION (1) WHICH USES THE MARSHALL-STEVENS INDEX INCORPORATED IN THE PROGRAM FOR THE YEAR 1975, BUT PERMITS THE USER TO SPECIFY AN ANNUAL INCREASE OTHER THAN 4.5 PERCENT BEYOND THE 1975 INDEX VALUE.

TYPE IN THE OPTION YOU PREFER
? 1

13A. TYPE IN THE YEAR OF INTEREST (OPTION 1 ONLY)
? 1975

ISOLATED OPERATIONS PRODUCING COKE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
59	COAL	1429000.0	0	1429000.0			28.580			RAW MATERIAL
63	SULFURIC ACID	18000.0	0	18000.0	.504				.011	
70	COKE	0.0	1000000	1000000.0	102.319	40.000			1.310	
72	AMMONIUM SULFATE	-18000.0	0	-18000.0				.720		BY-PRODUCT
82	SULFUR	6192.0	0	6192.0			.780			RAW MATERIAL
	TOTAL				102.823	40.000	29.360	.720	1.320	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING METHANOL

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	0.0	300000	300000.0	26.322	36.420			4.256	
4	CARBON MONOXIDE	438900.0	0	438900.0	29.536				15.675	
9	HYDROGEN	5226.3	0	5226.3			.209			RAW MATERIAL
59	COAL	235250.4	0	235250.4			4.705			RAW MATERIAL
	TOTAL				55.858	36.420	4.914	.000	19.931	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING FORMALDEHYDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	0	188550.0	19.288				2.694	
4	CARBON MONOXIDE	275848.7	0	275848.7	21.339				9.852	
9	HYDROGEN	3284.7	0	3284.7			.131			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
59	COAL	147854.9	0	147854.9			2.957			RAW MATERIAL
	TOTAL				80.147	36.480	3.088	0.000	16.117	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

CO-SITED OPERATIONS (COMPLEX)

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	300000	488550.0	37.919	36.420			6.979	
4	CARBON MONOXIDE	714748.7	0	714748.7	41.554				25.527	
9	HYDROGEN	8511.0	0	8511.0			.340			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
59	COAL	1812105.3	0	1812105.3			36.242			RAW MATERIAL
63	SULFURIC ACID	18000.0	0	18000.0	.504				.011	
70	COKE	0.0	1000000	1000000.0	102.319	40.000			1.310	
72	AMMONIUM SULFATE	-18000.0	0	-18000.0				.720		BY-PRODUCT
82	SULFUR	6192.0	0	6192.0			.780			RAW MATERIAL
	TOTAL				221.816	112.900	37.363	.720	37.398	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH
A DIFFERENT ANNUAL INCREASE IN PLANT COSTS ?
? NO

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR
ANOTHER COMPLEX ?
? YES

15B. DO YOU WANT TO USE THE SAME PLANT-COST BASIS IN
THIS ANALYSIS YOU CHOSE IN RESPONSE TO
STATEMENTS 12 AND 13 IN THE PREVIOUS ANALYSIS?
? YES

10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU
SPECIFY MERCHANT CAPACITIES ?
? 4

11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE
COMPLEX AND THEIR MERCHANT CAPACITIES, I.E.,
INDUSTRY NUMBER, CAPACITY (TONS/YEAR)
? 68,100000
? 83, 50000
? 67, 50000
? 51, 40000

ISOLATED OPERATIONS PRODUCING CALCIUM CARBIDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-48000.0	0	-48000.0				1.920		BY-PRODUCT
44	CARBON DIOXIDE	-77298.0	0	-77298.0				1.546		BY-PRODUCT
58	CALCIUM CARBONATE	188290.0	0	188290.0			.941			RAW MATERIAL
59	COAL	127330.7	0	127330.7			2.547			RAW MATERIAL
63	SULFURIC ACID	1229.4	0	1229.4	.081				.001	
68	CALCIUM CARBIDE	0.0	100000	100000.0	19.814	17.140			34.524	
69	CALCIUM OXIDE	99100.0	0	99100.0	1.390				.295	
70	COKE	68300.0	0	68300.0	15.633				.089	
72	AMMONIUM SULFATE	-1229.4	0	-1229.4				.049		BY-PRODUCT
82	SULFUR	422.9	0	422.9			.053			RAW MATERIAL
	TOTAL				36.918	17.140	3.541	3.515	34.909	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING PHOSGENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	14400.0	0	14400.0	2.701				.514	
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	-2923.2	0	-2923.2				.117		BY-PRODUCT
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
59	COAL	7718.4	0	7718.4			.154			RAW MATERIAL
63	SULFURIC ACID	360.0	0	360.0	.035				.000	
82	SULFUR	123.8	0	123.8			.016			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				27.854	25.000	3.108	15.844	14.562	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ACETYLENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-72048.0	0	-72048.0				2.882		BY-PRODUCT
44	CARBON DIOXIDE	-32018.3	0	-32018.3				.640		BY-PRODUCT
58	CALCIUM CARBONATE	77993.3	0	77993.3			.390			RAW MATERIAL
59	COAL	158813.4	0	158813.4			3.176			RAW MATERIAL
63	SULFURIC ACID	1845.3	0	1845.3	.107				.001	
67	ACETYLENE	0.0	50000	50000.0	7.335	49.000			1.190	
68	CALCIUM CARBIDE	150100.0	0	150100.0	26.329				51.820	
69	CALCIUM OXIDE	41049.1	0	41049.1	.750				.122	
70	COKE	102518.3	0	102518.3	20.774				.134	
72	AMMONIUM SULFATE	-1845.3	0	-1845.3				.074		BY-PRODUCT
82	SULFUR	634.8	0	634.8			.080			RAW MATERIAL
	TOTAL				55.296	49.000	3.646	3.596	53.268	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ISOPRENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-25649.1	0	-25649.1				1.026		BY-PRODUCT
9	HYDROGEN	18800.0	0	18800.0			.752			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
44	CARBON DIOXIDE	-11398.5	0	-11398.5				.228		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
58	CALCIUM CARBONATE	27765.6	0	27765.6			.139			RAW MATERIAL
59	COAL	56537.6	0	56537.6			1.131			RAW MATERIAL
63	SULFURIC ACID	656.9	0	656.9	.053				.000	
67	ACETYLENE	17800.0	0	17800.0	3.560				.424	
68	CALCIUM CARBIDE	53435.6	0	53435.6	12.778				18.448	
69	CALCIUM OXIDE	14613.5	0	14613.5	.364				.043	
70	COKE	36496.5	0	36496.5	10.082				.048	
72	AMMONIUM SULFATE	-656.9	0	-656.9				.026		BY-PRODUCT
82	SULFUR	226.0	0	226.0			.028			RAW MATERIAL
	TOTAL				43.545	56.000	14.050	1.280	21.821	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

CO-SITED OPERATIONS (COMPLEX)

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-131297.1	0	-131297.1				5.252		BY-PRODUCT
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	17792.0	0	17792.0			.712			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
44	CARBON DIOXIDE	-120714.8	0	-120714.8				2.414		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
58	CALCIUM CARBONATE	294048.9	0	294048.9			1.470			RAW MATERIAL
59	COAL	342681.6	0	342681.6			6.854			RAW MATERIAL
63	SULFURIC ACID	4091.7	0	4091.7	.184				.002	
67	ACETYLENE	17800.0	50000	67800.0	9.078	49.000			1.614	
68	CALCIUM CARBIDE	203535.6	100000	303535.6	43.104	17.140			104.792	
69	CALCIUM OXIDE	154762.6	0	154762.6	1.899				.461	
70	COKE	207314.8	0	207314.8	34.009				.271	
72	AMMONIUM SULFATE	-3731.7	0	-3731.7				.149		BY-PRODUCT
82	SULFUR	1407.5	0	1407.5			.177			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				130.101	147.140	24.151	23.542	124.046	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH
A DIFFERENT ANNUAL INCREASE IN PLANT COSTS ?
? NO

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR
ANOTHER COMPLEX ?
? YES

15B. DO YOU WANT TO USE THE SAME PLANT-COST BASIS IN
THIS ANALYSIS YOU CHOSE IN RESPONSE TO
STATEMENTS 12 AND 13 IN THE PREVIOUS ANALYSIS?
? YES

10. FOR HOW MANY INDUSTRIES IN THE COMPLEX WILL YOU
SPECIFY MERCHANT CAPACITIES ?
? 7

11. LIST THE CODE NUMBERS OF THE INDUSTRIES IN THE
COMPLEX AND THEIR MERCHANT CAPACITIES, I.E.,
INDUSTRY NUMBER, CAPACITY (TONS/YEAR)
? 70,1000000
? 3, 300000
? 27, 150000
? 68, 100000
? 83, 50000
? 67, 50000
? 51, 40000

ISOLATED OPERATIONS PRODUCING COKE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
59	COAL	1429000.0	0	1429000.0			28.580			RAW MATERIAL
63	SULFURIC ACID	18000.0	0	18000.0	.504				.011	
70	COKE	0.0	1000000	1000000.0	102.319	40.000			1.310	
72	AMMONIUM SULFATE	-18000.0	0	-18000.0				.720		BY-PRODUCT
82	SULFUR	6192.0	0	6192.0			.780			RAW MATERIAL
	TOTAL				102.823	40.000	29.360	.720	1.320	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING METHANOL

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	0.0	300000	300000.0	26.822	36.420			4.286	
4	CARBON MONOXIDE	438900.0	0	438900.0	29.536				15.675	
9	HYDROGEN	5226.3	0	5226.3			.209			RAW MATERIAL
59	COAL	235250.4	0	235250.4			4.705			RAW MATERIAL
	TOTAL				56.358	36.420	4.914	0.000	19.961	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING FORMALDEHYDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	0	188550.0	19.288				2.624	
4	CARBON MONOXIDE	275848.7	0	275848.7	21.339				9.852	
9	HYDROGEN	3284.7	0	3284.7			.131			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
59	COAL	147854.9	0	147854.9			2.957			RAW MATERIAL
	TOTAL				80.147	36.480	3.088	0.000	16.117	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING CALCIUM CARBIDE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-48000.0	0	-48000.0				1.920		BY-PRODUCT
44	CARBON DIOXIDE	-77298.0	0	-77298.0				1.546		BY-PRODUCT
58	CALCIUM CARBONATE	188290.0	0	188290.0			.941			RAW MATERIAL
59	COAL	127330.7	0	127330.7			2.547			RAW MATERIAL
63	SULFURIC ACID	1229.4	0	1229.4	.081				.001	
68	CALCIUM CARBIDE	0.0	100000	100000.0	19.814	17.140			34.524	
69	CALCIUM OXIDE	99100.0	0	99100.0	1.390				.295	
70	COKE	68300.0	0	68300.0	15.633				.089	
72	AMMONIUM SULFATE	-1229.4	0	-1229.4				.049		BY-PRODUCT
82	SULFUR	422.9	0	422.9			.053			RAW MATERIAL
	TOTAL				36.918	17.140	3.541	3.515	34.909	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING PHOSGENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	14400.0	0	14400.0	2.701				.514	
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	-2923.2	0	-2923.2				.117		BY-PRODUCT
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
59	COAL	7718.4	0	7718.4			.154			RAW MATERIAL
63	SULFURIC ACID	360.0	0	360.0	.035				.000	
82	SULFUR	123.8	0	123.8			.016			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				27.854	25.000	3.108	15.844	14.562	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ACETYLENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-72048.0	0	-72048.0				2.882		BY-PRODUCT
44	CARBON DIOXIDE	-32018.3	0	-32018.3				.640		BY-PRODUCT
58	CALCIUM CARBONATE	77993.3	0	77993.3			.390			RAW MATERIAL
59	COAL	158813.4	0	158813.4			3.176			RAW MATERIAL
63	SULFURIC ACID	1845.3	0	1845.3	.107				.001	
67	ACETYLENE	0.0	50000	50000.0	7.335	49.000			1.190	
68	CALCIUM CARBIDE	150100.0	0	150100.0	26.329				51.820	
69	CALCIUM OXIDE	41049.1	0	41049.1	.750				.122	
70	COKE	102518.3	0	102518.3	20.774				.134	
72	AMMONIUM SULFATE	-1845.3	0	-1845.3				.074		BY-PRODUCT
82	SULFUR	634.8	0	634.8			.080			RAW MATERIAL
	TOTAL				55.296	49.000	3.646	3.596	53.268	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

ISOLATED OPERATIONS PRODUCING ISOPRENE

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
4	CARBON MONOXIDE	-25649.1	0	-25649.1				1.026		BY-PRODUCT
9	HYDROGEN	18800.0	0	18800.0			.752			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
44	CARBON DIOXIDE	-11398.5	0	-11398.5				.228		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
58	CALCIUM CARBONATE	27765.6	0	27765.6			.139			RAW MATERIAL
59	COAL	56537.6	0	56537.6			1.131			RAW MATERIAL
63	SULFURIC ACID	656.9	0	656.9	.053				.000	
67	ACETYLENE	17800.0	0	17800.0	3.560				.424	
68	CALCIUM CARBIDE	53435.6	0	53435.6	12.778				18.448	
69	CALCIUM OXIDE	14613.5	0	14613.5	.364				.043	
70	COKE	36496.5	0	36496.5	10.082				.048	
72	AMMONIUM SULFATE	-656.9	0	-656.9				.026		BY-PRODUCT
82	SULFUR	226.0	0	226.0			.028			RAW MATERIAL
	TOTAL				43.545	56.000	14.050	1.280	21.821	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

CO-SITED OPERATIONS (COMPLEX)

ID	PLANT/MATERIAL	CAPTIVE PRODN. TPY	MERCHANT PRODN. TPY	TOTAL PRODN. TPY	PLANT * COST MM$	PRODUCT VALUE MM$PY	RAW MATL. COST MM$PY	BY-PRODUCT CREDIT MM$PY	POWER MW	REMARKS
3	METHANOL	188550.0	300000	488550.0	37.919	36.420			6.979	
4	CARBON MONOXIDE	583451.6	0	583451.6	36.050				20.838	
7	CHLORINE	36000.0	0	36000.0	17.794				12.857	
9	HYDROGEN	43765.5	0	43765.5			1.751			RAW MATERIAL
19	ACETONE	40000.0	0	40000.0			12.000			RAW MATERIAL
27	FORMALDEHYDE	0.0	150000	150000.0	39.520	36.480			3.571	
44	CARBON DIOXIDE	-120714.8	0	-120714.8				2.414		BY-PRODUCT
51	ISOPRENE	0.0	40000	40000.0	16.708	56.000			2.857	
53	SODIUM CHLORIDE	65880.0	0	65880.0			2.938			RAW MATERIAL
54	SODIUM HYDROXIDE	-40680.0	0	-40680.0				15.727		BY-PRODUCT
58	CALCIUM CARBONATE	294048.9	0	294048.9			1.470			RAW MATERIAL
59	COAL	2084411.7	0	2084411.7			41.688			RAW MATERIAL
63	SULFURIC ACID	22091.7	0	22091.7	.579				.013	

67	ACETYLENE	17800.0	50000	67800.0	9.078	49.000			1.614	
68	CALCIUM CARBIDE	203535.6	100000	303535.6	43.104	17.140			104.792	
69	CALCIUM OXIDE	154762.6	0	154762.6	1.899				.461	
70	COKE	207314.8	1000000	1207314.8	116.743	40.000			1.581	
72	AMMONIUM SULFATE	-21731.7	0	-21731.7				.869		BY-PRODUCT
82	SULFUR	7599.5	0	7599.5			.958			RAW MATERIAL
83	PHOSGENE	0.0	50000	50000.0	7.324	25.000			1.190	
	TOTAL				326.719	260.040	60.805	19.010	156.754	

* CAPITAL COSTS ONLY. NOT INCLUDED ARE OFFSITE FACILITIES, LAND COSTS, AND UTILITIES.

14. DO YOU WISH TO ANALYZE THE SAME COMPLEX BUT WITH
A DIFFERENT ANNUAL INCREASE IN PLANT COSTS ?
? NO

15A. DO YOU WANT TO PERFORM AN ECONOMIC ANALYSIS FOR
ANOTHER COMPLEX ?
? NO

16. WOULD YOU LIKE TO SPECIFY ANOTHER CORE OF
INDUSTRIES AND BEGIN ANOTHER SEARCH FOR
CO-SITING CANDIDATES FOR THIS CORE ?
? NO
45.883 CP SECONDS EXECUTION TIME
/

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The tasks described in the previous sections of this report provide the basis for several conclusions. These are summarized below.

1. Synergistic co-siting of carefully selected industrial activities can provide mutually beneficial utilization of energy, raw materials, co-products, land, plant wastes and transportation facilities as well as promote greater economical attractiveness of pollution control measures and resource recovery.

2. The technical factors having the greatest influence on the selection of co-sited groupings can be identified and classified using the procedures developed on this program.

3. The systematic search and screening procedure developed on this program for identifying co-siting candidates can be automated into a user-interactive mode to investigate (a) matching of existing plants, (b) matching of existing plants with new plants, and (c) development of entirely new complexes.

4. Economic evaluation techniques can be automated into a user-interactive mode to yield cost-benefit comparisons between conventional and co-siting methods of industrial operations.

5. Additional parameters exist that add to the already established benefits of synergistic co-siting.

6. Significant user interest exists at the regional, state, and national levels in the application of synergistic co-siting to meet a variety of needs.

7. Relevant regional application examples, selected on the basis of a review of mineral resources in the Appalachian Region and close communication with regional industrial planners in the North Georgia APDC, demonstrate the use of the methodology developed on this study.

4.2 RECOMMENDATIONS

From the conclusions presented in Section 4.1, it has been established that synergistic co-siting can be used effectively in planning industrial development. Specific recommendations for implementing the use of the co-siting methodology that was developed on this program are summarized below.

- Additional conferences and workshops should be held for potential users and planners.
- Applications should be extended to the entire Appalachian Region, with expansion of the data base as required
- The results of this study should be applied, in concert with regional impact analyses, in the formulation of policies and options for the planning of industrial development in the Appalachian Region
- Appropriate prototype synergistic co-sited groupings should be selected to demonstrate their benefits for the Appalachian Region
- Appropriate incentives for widespread acceptability and implementation of the synergistic co-siting concept should be identified and developed

5.0 IMPLICATIONS FOR FUTURE WORK

There are a number of exciting and user-oriented extensions of the methodology developed in this work that have been identified during the course of the present study. The more significant possibilities are listed below.

- Expansion of the data base both "vertically" and "horizontally." Vertical expansion would bring additional commodities into the data base to accommodate more product possibilities, backward and forward integration in a co-siting venture, waste and effluent processing, energy-conservation schemes, etc. Typical horizontal expansions would include more detailed cost information for each commodity, such as unit labor costs, unit land requirements, off-site facility requirements, working-capital requirements, etc.

- Extension of the coupling analysis to provide for total systems integration, and incorporation of modularization techniques and synergistic interface visualization -- an adaptation of computer aided graphic design.

- Extension of the economic analysis to yield return on investment, discounted cash flow, etc.

- Incorporation of optimization techniques to permit consideration of alternate raw material sources and alternate production processes.

APPENDICES

APPENDIX A

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33. J. E. Haselbarth, "Updated Investment Costs for 60 Types of Chemical Plants," Chem. Engrg., 214-215 (Dec. 4, 1967).

34. F. A. Holland, F. A. Watson and J. K. Wilkinson, "How to Estimate Capital Costs," Chem. Engrg., 71-76 (April 1, 1974).

35. O. T. Zimmerman, "Process Plant Costs," Cost Engrg., 14-19 (July, 1965).

36. "1975 Petrochemical Handbook Issue," Hydrocarbon Processing, 97-224 (November 1975).

37. "Problems of Input-output Tables and Analysis," Series F, No. 14, United Nations, New York (1966).

38. D. M. Himmelblau, "Decomposition of Large Scale Systems," Chem. Engrg. Sci., 21, 425-438 (1966).

39. C. M. Crowe, et al., "Chemical Plant Simulation," Prentice-Hall, Englewood Cliffs, N. J. (1971).

40. T. C. Lowe, "An Algorithm for Rapid Calculation of Products of Boolean Matrices," Software Age, 35-36 (March 1968).

41. M. J. Bending and H. P. Hutchison, "The Calculation of Steady State Incompressible Flow in Large Networks of Pipes," Chem. Engrg. Sci., 28, 1857-1864 (1973).

42. G. L. Perry and J. T. Sommerfeld, "Fortran Programming Aids," Software Age, 4, No. 10/11, 11-13 (1970).

43. O. H. Hammond and R. E. Baron, "Synthetic Fuels: Prices, Prospects and Prior Art," American Scientist, 64, 407-417 (1976).

44. K. W. Foo and I. Shortland, "Compare CO Production Methods," Hydrocarbon Processing, 149-152 (May, 1976).

APPENDIX B

MINERALS OF THE GEORGIA APPALACHIAN REGION *

Aggregate - Light Weight. Slates suitable for production of light weight aggregates are found in Polk County. Production has taken place since the early 1960's. Slates and shales suitable for light weight aggregates should be found in the Paleozoic shales in northwest Georgia other than Polk County, but exploration and testing will be required for proof. Supplies are considered good.

Anon., 1952, Georgia Mineral Newsletter; vol. V, no. 2, p. 29.

Furcron, A. J., 1953, Mineral Industry in Georgia 1940-1950; Georgia Geol. Surv., Bull. 60, p. 56-60.

Tenhart, W. B., 1955, Producing Lightweight Aggregate from Slate; Georgia Mineral Newsletter; vol. VIII, no. 1, p. 1-9.

Map Index No. 28.

Apatite. Apatite, a calcium phosphate, was found as a mineral specimen in White County.

Anon., 1955, Georgia Mineral Newsletter; vol. VIII, no. 2, p. 77.

Teague, K. H., Asbestos in Georgia; Georgia Mineral Newsletter; 1956, vol IX, no. 1, p. 207.

Teague, K. H., 1957, Mineral Resources of Union, Towns, Lumpkin, and White Counties; Georgia Mineral Newsletter; 1957, vol. X, no. 2, p. 52.

Hopkins, O. B., 1914, A Report on the Asbestos, Talc, and Soapstones of Georgia; Ga. Geol. Surv., Bull. 29, 319 pp.

Map Index No. 12.

Arsenopyrite. Arsenopyrite has been found as scattered mineral specimens in Cherokee, Dawson, and Lumpkin. In Virginia, arsenopyrite has been found associated with Cassiterite (tin ore). No such association has been found in Georgia but should be investigated.

Anon., 1948, Georgia Mineral Newsletter; vol. II, no. 3, no. 9.

Map Index Nos. 11, 18, 24.

Asbestos. Asbestos found in Georgia is of the anthophyllite variety. Mining operations have been in the northeast part of the State. The grades of asbestos found in Georgia are of marginal economic value; hence mining has not had long term continuity.

Bowles, O., 1937, Asbestos; U. S. Bureau of Mines, Bull. 403, IV.

Peyton, G., Mineral Production in Georgia, 1934, 1955; Georgia Mineral Newsletter; vol. IX, no. 4, p. 113-115.

Map Index Nos. 8,9,11,12,13,24,31.

* Map Indices refer to Table B-I and Figure B-1, pages B-13 and B-14, respectively.

Barite. Barite is commercially produced in Bartow County from saprolitic clays that are residuary from the weathering of limestone. Two companies are operating currently. Indicated reserves are on an order of magnitude of 25 years from 1976 at present operating rates.

Hull, J.P.D., 1920, Barytes Deposits of Georgia; Ga. Geol. Surv., Bull. 36, 146 pp.

Brobst, D. A., 1975, Barium Minerals; in Industrial Minerals and Rocks; 4th ed., p. 433.

Map Index Nos. 4,5,16,22,23,24,28.

Bauxite. The first bauxite discovered and mined in North America was in Bartow County in 1888. The reserves of bauxite in the Appalachian area of Georgia are now essentially depleted. Production in recent years was directed toward the chemical market rather than as a source of aluminum metal.

Shaffer, J. W., 1975, Bauxitic Raw Materials; in Industrial Minerals and Rocks, 4th ed., p. 452.

Map Index Nos. 2,5,16,22,23,28.

Bentonite. Bentonites found in the Appalachian area of Georgia are Metabentonites of Ordovician age. There has been no commercial use of these clays to the present.

Kay, G. W., 1935, Distribution of Ordovician Altered Volcanic Materials and Related Clays; Geol. Soc. Am., Bull, 46, no. 2, p. 225-244.

Map Index Nos. 1,2,3,15.

Beryl. Beryl has been found at scattered pegmatite occurrences as mineral specimens.

Georgia Mineral Newsletter; 1948; vol. 1, no. 1, p. 1-2, p. 4.

Georgia Mineral Newsletter; 1953, vol. VI, no. 2, p. 40.

Map Index No. 5.

Bloating-granite. A granitic type rock found near Chatsworth, Ga., "bloats" or expands at approximately 2800°F or roughly 1200°F more than necessary to expand slates to a light weight aggregate. The material is not commercial.
Unpublished research, Georgia Institute of Technology, 1958.
Map Index No. 5.

Clay. Brick Clay is found in scattered localities in northwest Georgia. The clay is being produced currently. Brick Clay is thought to be in very good supply.

Butts, C. and Gildersleeve, B., 1948, Geology and Mineral Resources of the Paleozoic Area in Northwest Georgia; Ga. Geol. Survey, Bull. 54, p. 1-176.

Map Index Nos. 2,6,11,16,18,22,23,28,32.

Chromite. Chromite has been reported in Towns County; grade and reserves are not known.

Hunter, C. E., 1938, Chromite in Western North Carolina and North Georgia; T.V.A., Geol. Bull. 10, p. 18-20.

Map Index No. 8.

Coal. Coal of Mississippian Age has and is being mined in Dade County with some coal being present in Walker and Chattooga Counties. The quantity is relatively small.

Georgia Mineral Newsletter, 1950, v. III, no. 2, p. 44.

Map Index Nos. 1,2,15.

Cobalt. Cobalt has been found associated with low grade mineralized areas in Bartow, Floyd, and Polk Counties.

Pierce, W. G., 1944, Cobalt-Bearing Manganese Deposits of Alabama, Georgia, and Tennessee; U.S. Geol. Surv., Bull. 940-J, v. IV, p. 265-285.

Map Index Nos. 22,23,28.

Copper. Copper has been found in a wide band of counties across the northern part of Georgia. Most deposits are found in the Brevard Shear Zone in the Murphy Marble Belt. The Copper Hill deposit of Tennessee extends across the border into Georgia. No production is current in Georgia. Deposits of copper are scattered and not thought to be extensive. An extension of the Copper Hill deposit could be an exception. Detailed geochemical and geophysical work should be done to better delineate known occurrences.

Of numerous references, the following were selected:

Furcron, A. S., 1952, Georgia's Copper Deposits; Georgia Mineral Society Newsletter, v. V, no. 5, p. 137.

Kendall, H. F., 1954, Operations of the Tennessee Copper Company on Sulphide Ores of the Ducktown Basin, Tenn.; Ga. Mineral Newsletter, v. VII, no. 2, p. 76.

Ross, Clarence S., 1935, Origin of the Copper Deposits of the Ducktown Type in the Southern Appalachian Region; U. S. Geol. Surv. Prof Paper 179.

Map Index Nos. 6,7,8,9,11,12,13,18,19,20,23,24,25,32,33,34.

Corundum. Corundum is a natural, crystalline form of aluminum oxide (Al_2O_3) that is both tough and hard. In natural hardness, it ranks next to diamond. Gem varieties are ruby and sapphire. Corundum is an excellent abrasive but does not command the market it did before the event of silicon carbide (Carborundum). Deposits are scattered across north Georgia with no large deposits.

Anon., 1950, Georgia Mineral Newsletter, v. III, no. 2, p. 48.

King, F. P., 1894, A Preliminary Report on the Corundum Deposits of Georgia; Ga. Geol. Surv., Bull. 2, 133 pp.

Map Index Nos. 7,8,9,11,12,13,18,19,24,25,29,33,34,35.

Diamond. Single diamond crystals have been found at scattered locations across north Georgia.

Anon., 1948, Georgia Mineral Newsletter, v. 1, no. 6, p. 10.

Blank, Eugene, W., 1934, Diamond Finds in the United States; Rocks and Minerals, v. 9, no. 10.

Map Index Nos. 7,8,9,11,12,13,18,19,20,24,25,29,30,33,34,35.

Diaspore. Diaspore is reported from Rabun County.

Anon., 1951, Georgia Mineral Newsletter; v. IV, no. 1, p. 4.

Map Index No. 9.

Dolomite. Dolomite is found extensively in the lower Paleozoic rocks of northwest Georgia. Dolomite is also found in Lumpkin, Hall, and Habersham Counties in older rocks. The grade of dolomite varies considerably, ranging from very pure dolomite of near theoretical composition to dolomitic limestones with a high impurity content of clays and other deleterious minerals.

Furcron, A. S., 1942, Dolomites and Magnesium Limestones in Georgia; Ga. Geol. Surv., Info. Circ. 14, 30 pp.

McLemore, W. H., and Hurst, V. J., 1970, The Carbonate Rocks in the Coosa Valley Area; U. S. Dept. Commerce, Econ. Dev. Admin., Tech. Asst. Proj., 170 pp.

Map Index Nos. 2,3,4,5,10,11,13,15,16,19,22,23,28.

Feldspar. Feldspar is found in the crystalline rocks of the Appalachian area as a constituent mineral of granite-type rocks and pegmatites. Rocks of this type are in the Blue Ridge and Piedmont portions of the Appalachian area of Georgia.

Map Index Nos. 9,11,12,14,17,24,25,29,32,33.

Fluorite. Occurrences of fluorite have been reported in extreme northwest Georgia. No commercial investigations are known to have established quality and quantity.

Anon., 1948, Georgia Mineral Newsletter; v. II, no. 4, p. 17.

Anon., 1951, Georgia Mineral Newsletter; v. IV, no. 3, p. 87.

Butts, C. and Gildersleeve, B., 1948, Geology and Mineral Resources of the Paleozoic Area in Northwest Georgia; Ga. Geol. Surv., Bull. 54, p. 1-178.

Map Index Nos. 3,15,16.

Garnet. Garnet is generally classed as an abrasive although some garnets may also qualify as gem stones. Garnet is found in the metamorphic rocks of the Blue Ridge and Piedmont areas.

Bayley, W. S., 1928, Geology of the Tate Quadrangle, Georgia; Ga. Geol. Surv., Bull. 43, 170 pp.

Map Index Nos. 8,11,17,19,24.

Glass Sands. Sand and Quartz glass quality is found throughout north Georgia as sandstone, quartzite, and as part of the recoverable product from the flotation of crushed granite. Adequate supply for glass manufacture is throught to be available for a glass industry.

Anon., 1940, Glass Sands and Glass Making Materials in Georgia; Ga. Dept. Mines, Mining, and Geology, Info. Cir. 11.

Map Index Nos. -- See Granite and Quartz.

Gold. Georgia is where the statement "Thar's gold in them thar hills" originated. A federal mint operated at Dahlonega until 1860. To find gold today for a commercial market would take extensive and intensive geochemical and geological study and investigation. The unanswered question is whether the cost of exploration would be greater than the value of gold discovered.

Anon., 1948, Georgia Mineral Newsletter; v. I, no. 8, p. 13.

Pardee, J. T., and Parks, C. F., Jr., 1948, Gold Deposits of the Southern Piedmont: U.S. Geol. Surv. Prof. Paper 213, 156 pp.

References are extensive.

Map Index Nos. 6,7,8,9,10,11,12,13,14,17,18,19,23,24,25,27,29,32,33,34.

Granite. Granite is found throughout the Blue Ridge and Piedmont portions of the Appalachian area of Georgia. Granite is abundant in Georgia.

Watson, T. L., 1902, A Preliminary Report on a Part of the Granites and Greisses of Georgia; Ga. Geol. Surv., Bull. 9-A, 367 pp.

Map Index Nos. 5,6,17,24,25,30,32,34,35.

Graphite. Graphite is in scattered deposits throughout the crystalline areas of the Georgia Appalachian region. Commercial amounts and grades have not been determined. There is a potential of graphite availability with applied modern technologies.

Anon., 1948, Georgia Mineral Newsletter; v. I, no. 6, p. 10-12.

Map Index Nos. 6,7,8,10,13,17,19,23,32,33,34,35.

Iron Ore. The iron ores of the Appalachian region of Georgia are of several types. Major production has been from the brown ores. Production from the Clinton red ores ceased shortly after World War I and has not been resumed. Magnetite has not been a commercial source of iron in Georgia.

Present reserves of brown ores are marginal at best. Production is market dependent with most of the ore being shipped to Birmingham, Ala., or Gadsden, Ala. Bartow County has been the chief area from which brown iron ore has been produced.

Anon., 1950, Georgia Mineral Newsletter; v. III, no. 5, p. 161.

Numerous other references exist.

Map Index Nos. 1,2,3,4,5,6,7,8,10,11,13,15,16,17,18,22,23,24,28,29,32.

Kaolin. Kaolin (mineral name Kaolinite) is a clay usually derived from the weathering of feldspar or feldspathic rocks. As a clay, however, it can be and is transported many miles from a feldspar source and may be found associated with sedimentary rocks as strata or as an impurity of other sediments.

Hosterman, J. W., Patterson, S. H., Sweeney, J. W., and Hartwell, J. W., 1968, Clay; in Mineral Resources of the Appalachian Region; U. S. Geol. Surv., Prof. Paper 580, p. 182-187.

Veatch, J. O., 1909, Second Report on the Clay Deposits of Georgia; Ga. Geol. Surv., Bull. 18.

Map Index Nos. 9,10,13,17,18,22,23,28.

Kyanite. Kyanite is an aluminum silicate metamorphic mineral whose chief use is in refractories. In Georgia's Appalachian region, kyanite is found in the north central and northeast part of the State. Kyanite has been found in Rabun, Habersham, White, Fannin and Union Counties and mined in Habersham County. Currently there is no production in any of these areas. The outlook is regarded as very marginal because of the competition from the Graves Mountain deposit in Lincoln County, Georgia plus the need for a large captive market to justify the mining and beneficiation equipment investment.

Espenshade, G. H., and Eilertsen, A., 1968, Kyanite Group Minerals; in Mineral Resources of the Appalachian Region, U. S. Geol. Surv., Prof. Paper 580, p. 307-309.

Hurst, V. J., and Crawford, T. J., 1964, Exploration for Mineral Deposits in Habersham County, Georgia; Wash., D.C., U.S. Dept. of Commerce, Area Redevelopment Admin., 180 pp.

Map Index Nos. 9,10,13,17,18,24.

Lead and Zinc. Lead and zinc have not been produced in Georgia. These metals have been found in limestone deposits west of Cartersville, Ga., and associated with both massive sulfide deposits and gold areas of the Blue Ridge and Piedmont of the Georgia Appalachians.

Extensive exploration for lead and zinc was done by a major oil company in the area west of Cartersville, Ga., in the early 1970's, but there have been no reports of planned exploitation.

Wedow, H., Jr., Heyl, H. V., and Sweeney, J. W., 1968, Zinc and Lead; in Mineral Resources of the Appalachian Area, U. S. Geol. Surv., Prof. Paper 580, p. 450-466.

Hurst, V. J., and Crawford, T. J., 1970, Sulfide Deposits in the Coosa Valley Area, Georgia; U. S. Dept. Commerce, Econ. Dev. Admin., Tech. Asst. Proj., 190 pp.

Map Index Nos. 1,3,5,6,11,19,24,30.

Limestone. Limestone is found throughout the Paleozoic sediments of northwest Georgia. Some marbles of northeast Georgia have been reported as limestone in the past but are more properly designated as marble. Of numerous references available, the following were selected:

Ericksen, G. E., and Cox, D. P., 1968, Limestone and Dolomite; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 227-252.

McLemore, W. H., and Hurst, V. J., 1970, The Carbonate Rocks in the Coosa Valley Area, Georgia; U.S. Dept. Commerce, Econ. Dev. Admin., Tech. Asst. Proj., 170 pp.

Map Index Nos. 1,2,3,4,6,10,15,16,17,22,23,24,28.

Manganese. Manganese ore bodies are small, diffuse and erratic. In general, manganese is found in residual clay bodies with the nodules of manganese ores scattered, like raisins in a cake. Exploration is difficult. Small amounts of manganese may be found in the Paleozoic area of northwest Georgia with occurrences elsewhere being principally mineral specimens.

Dorr, J.V.N., II, and Sweeney, J. W., 1968, Manganese; in U.S. Geol. Surv., Paper 580, p. 416-424.

Map Index Nos. 1,2,3,4,5,6,8,10,11,13,17,22,23,24,25,28,29,32.

Marble. Marble is found somewhat extensively in the Murphy Marble Belt. It is also found in other metamorphic areas. Marble is mined by several companies, but most is used for crushed stone or ground to very fine powder. Dimension stone marble is quarried near Tate, Ga. Marble is considered to be in good supply.

Newman, W. L., Stansfield, R. G., and Eilertson, N. A., 1968, Marble and Limestone; in U.S. Geol. Surv. Prof. Paper 580, p. 192-198.

Map Index Nos. 4,6,11,13,16,17,22,24,32.

Ochre. Ochre is mined for pigment use. Most ochre is mined near Cartersville, Ga. Reserves are not known.

Kesler, T. L., 1950, Geology and Mineral Deposits of the Cartersville District, Ga.; U.S. Geol. Surv. Prof. Paper 224.

Map Index Nos. 22,23.

Oil and Gas. No oil or gas has been produced in the Appalachian Region of Georgia. Structures suitable for the accumulation of oil and gas are found in the Paleozoic rocks of northwest Georgia and may be a source of production in the future.

Unpublished Research, Georgia Institute of Technology.

Map Index Nos. 1,2,3,22,35.

Olivine. Olivine is used for refractory products. Sources of olivine are found in the ultramafic rocks of north Georgia.

Hunter, C. E., 1941, Fosterite Olivine Deposits of North Carolina and Georgia; Ga. Geol. Surv., Bull. 47.

Map Index Nos. 8,9.

Pyrite. Pyrite is found scattered throughout the Blue Ridge and Piedmont areas. Pyrite has not been produced in Georgia since about the turn of the century and certainly none since before World War I.

Kinkel, A. R., Feitler, S. A., and Hubbs, R. G., 1968, Copper and Sulfur; in U.S. Geol. Surv. Prof. Paper 580, p. 378-385.

Map Index Nos. 6,8,9,11,12,13,19,20,22,23,24,29,32,33,34.

Quartz. Quartz is found in the Paleozoic area of northwest Georgia as an ingredient of sandstones, as a component of pegmatites, and as a product in the flotation of fine, ground granite. There is no commercial production of quarts.

Unpublished research, Georgia Institute of Technology.

Map Index Nos. 4,6,8,9,10,11,17,18,22,32,33,35.

Salt. Salt is not produced in Georgia. A salty spring with the salt equivalent of sea water is known in Douglas County and a well is reported in Dade County to have water containing a concentration of salt ten times that of sea water. The possibility of salt strata exists. The probability of a viable salt industry appears remote at present.

McCallie, S. W., 1913, Mineral Springs of Georgia; Ga. Geol. Surv., Bull. 20, 190 pp.

Croft, M. G., 1964, Geology and Ground Water Resources of Dade County, Ga.; Ga. Geol. Surv., Info. Circ. 26, 17 pp.

Map Index Nos. 1,34.

Sand. See Quartz. Sand for construction is composed of local alluvial deposits.

Sandstone. Dimension sandstone is available at four locations in northwest Georgia. No production or reserve estimates are known. Sandstone is also available for crushed stone or as a source of quartz. Local conditions of grain size, composition, degree of weathering, and parting or jointing will be deciding factors in the use of sandstone.

Newman, W. L., Stansfield, R. G., and Eilertson, N. A., 1968, Dimension Stone; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 190, 198-202.

Map Index Nos. 1,2,3,15,22,23.

Sapphire. Sapphire has been found as mineral and gem specimens from pegmatites of north Georgia.

Unpublished research, Georgia Institute of Technology.

Map Index No. 9.

Shale. Shale is a sedimentary rock usually composed of compacted clay minerals. In northwest Georgia, it has been used as a source material in making brick. Shales are found in the Paleozoic region of northwest Georgia as part of the sedimentary sequences.

Butts, C., and Gildersleeve, B., 1948, Geology and Mineral Resources of the Paleozoic Area in Northwest Georgia; Ga. Dept. Mines, Mining, and Geol., Bull. 54, 176 pp.

Map Index Nos. 1,2,3,4,5,15,16,22,23,28.

Sillimanite. Sillimanite is an aluminum silicate similar to kyanite in use and origin. The same general location and references used for kyanite may be used. Sillimanite is not currently being produced, however.

Reference: See Kyanite

Map Index Nos. 6,7,8,11,12.

Slate. Slate is a metamorphic rock used primarily in the construction industry as a roofing material and for flagstones and flooring. Some weathered slate is used as the raw material for light weight aggregate. Production of slate for flagstones has taken place in Fannin County, Georgia.

Newman, W. L., Stansfield, R. G., and Eilertsen, N. A., 1968, Slate; in U.S. Geol. Surv. Prof. Paper 580, p. 204-205.

Silver. Silver found in Georgia has been associated with sulfide mineralization and with gold. Two thousand troy ounces of silver were produced in Georgia as associated with gold or copper before 1941 with only 20 ounces since 1941. Most of this was from the Appalachian Region in Georgia.

Luttrell, G. W., and Stansfield, R. G., 1968, Silver; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 426-430.

Map Index No. 10.

Soapstone. Soapstone is a metamorphic rock associated with ultrabasic intrusives and some metamorphosed carbonates. Soapstones in Georgia are in the north Georgia counties, being approximately in the center of the Gold Belt. In general, soapstones are similar to talcs, but less pure.

Reference: See Talc.

Map Index Nos. 4,5,7,11,12,13,14,18,24,29,30,33,34,35.

Talc. Talc produced in Georgia is from Murray County near Chatsworth. Other talc is found along the Murphy Marble Belt. Several grades of talc are produced. Reserves are not known.

Wedow, H., Jr., and Sweeney, J. W., 1968, Talc, Soapstone, Pyrophyllite, and Sercite Schist; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 355-361.

Needham, R. E., and Hurst, V. J., 1970, Talc Deposits in the Coosa Valley Area, Georgia; U.S. Dept. Commerce, Econ. Dev. Admin., Tech. Asst. Proj., 58 pp.

Map Index Nos. 5,6,10,17,23,24.

Tin. Known deposits of tin in the Appalachian Region are either too small or too low in grade to permit profitable operation. Tin deposits in the Appalachian area of Georgia are usually associated with gold deposits.

Bryan, T. C., 1955, The Gold Rush in Georgia; Georgia Mineral Newsletter, 1955, vol. VIII, no. 4, p. 131.

Map Index Nos. 11,12.

Titanium. Rutile and ilmenite are the two titanium minerals usually exploited for their titanium content. Rutile is an impure TiO_2 which may contain up to 10 percent impurities, usually as iron oxides. Its formula is listed as TiO_2. Rutile in the Appalachian area of Georgia occurs as random scattered crystals in pegmatite. Some crystals may be quite large (several inches) and suitable as mineral specimens. The economics of mining and concentration mitigate against their commercial use. In weathered areas of the pegmatites, the rutile crystals may be found in a veneer of larger concentrations than may be experienced in the rock.

Ilmenite is an iron-titanium oxide ($FeTiO_3$). As a primary occurrence, ilmenite is frequently found associated with magnetite in anorthosites. In Georgia's Appalachian Region ilmenite is found associated with an anorthosite in the Lake Allatoona area. The ilmenite, per se, in this body contains about 55 percent TiO_2. Concentration, in situ, ranges up to 5 percent in the saprolite of the anorthosite. Environmental considerations related to the proximity to Lake Allatoona will probably prevent the development

of this ore body.

Herz, N., and Eilertson, N. A., 1968, Titanium; in Mineral Resources of the Appalachian Area, U.S. Geol. Surv., Prof. Paper 580, p. 437-443.

Elston, L. W., Husted, J. E., Long, L. T., Munoz, M. F., and Ostrander, C. C., 1970, Mineral Exploration of the Allatoona Dam, (Ga.) Quadrangle; Engineering Experiment Station,, Ga. Inst. of Tech., Project E-100-572, 36 pp.

Map Index Nos. 8,11,14,17,23,24,30.

Tungsten. Ten localities are reported in Appalachia for minerals containing tungsten. All contain small concentrations and no production is recorded. All are associated with copper deposits or placers.

Laurence, R. A., 1968, Tungsten; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 443.

Map Index No. 12.

Uranium. Uranium in the Appalachian Region of Georgia is found in the Chattanooga shale of northwest Georgia. Concentration of uranium is on an order of tens of grams of uranium per ton of shale. The supply of shale is very large, but the concentration of uranium is too low to be economical under present conditions.

Butler, A. P., Jr., and Stansfield, R. G., 1968, Uranium; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 443-449.

Map Index Nos. 8,29.

Vermiculite. Vermiculite is a member of the mica family of minerals that expands to approximately 20 times its volume on heating. It is used for insulation and as a light weight aggregate. Georgia deposits of vermiculite are concentrated in the extreme northeast part of the State with scattered deposits reported across the Georgia Appalachian Region. No production is noted and reserves are not known.

Bush, A. L., and Sweeney, J. W., 1968, Vermiculite; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 220-224.

Map Index Nos. 8,9.

Water for Power. There were three developed and five undeveloped water power sites in the Appalachian Region of Georgia as of 1968. Since then the Carters Dam is being added and either is or will be producing in the near future.

Johnson, A., 1968, Waterpower Resources; in Mineral Resources of the Appalachian Region, U.S. Geol. Surv., Prof. Paper 580, p. 48-51.

Map Index Nos. 9,13,14,23,25,30,33,35.

Zircon. Zircon has been found scattered throughout the Appalachian Region in granite composition rocks and with the acid phase of filter press zoning of anorthosites. No commercial concentrations are known in the Appalachian Region of Georgia.

Unpublished research, Georgia Institute of Technology.

Map Index Nos. 9,17,22,23.

Table B-I

COUNTIES OF GEORGIA'S APPALACHIAN REGION (WITH MAP INDEX NUMBER)

1. Banks (20)
2. Barrow (31)
3. Bartow (23)
4. Carroll (33)
5. Catoosa (3)
6. Chattooga (15)
7. Cherokee (24)
8. Dade (1)
9. Dawson (18)
10. Douglas (34)
11. Fannin (6)
12. Floyd (22)
13. Forsyth (25)
14. Franklin (21)
15. Gilmer (10)
16. Gordon (16)
17. Gwinnett (30)
18. Habersham (13)
19. Hall (19)
20. Haralson (32)
21. Heard (35)
22. Jackson (26)
23. Lumpkin (11)
24. Madison (27)
25. Murray (5)
26. Paulding (29)
27. Pickens (17)
28. Polk (28)
29. Rabun (9)
30. Stephens (14)
31. Towns (8)
32. Union (7)
33. Walker (2)
34. Whitfield (4)
35. White (12)

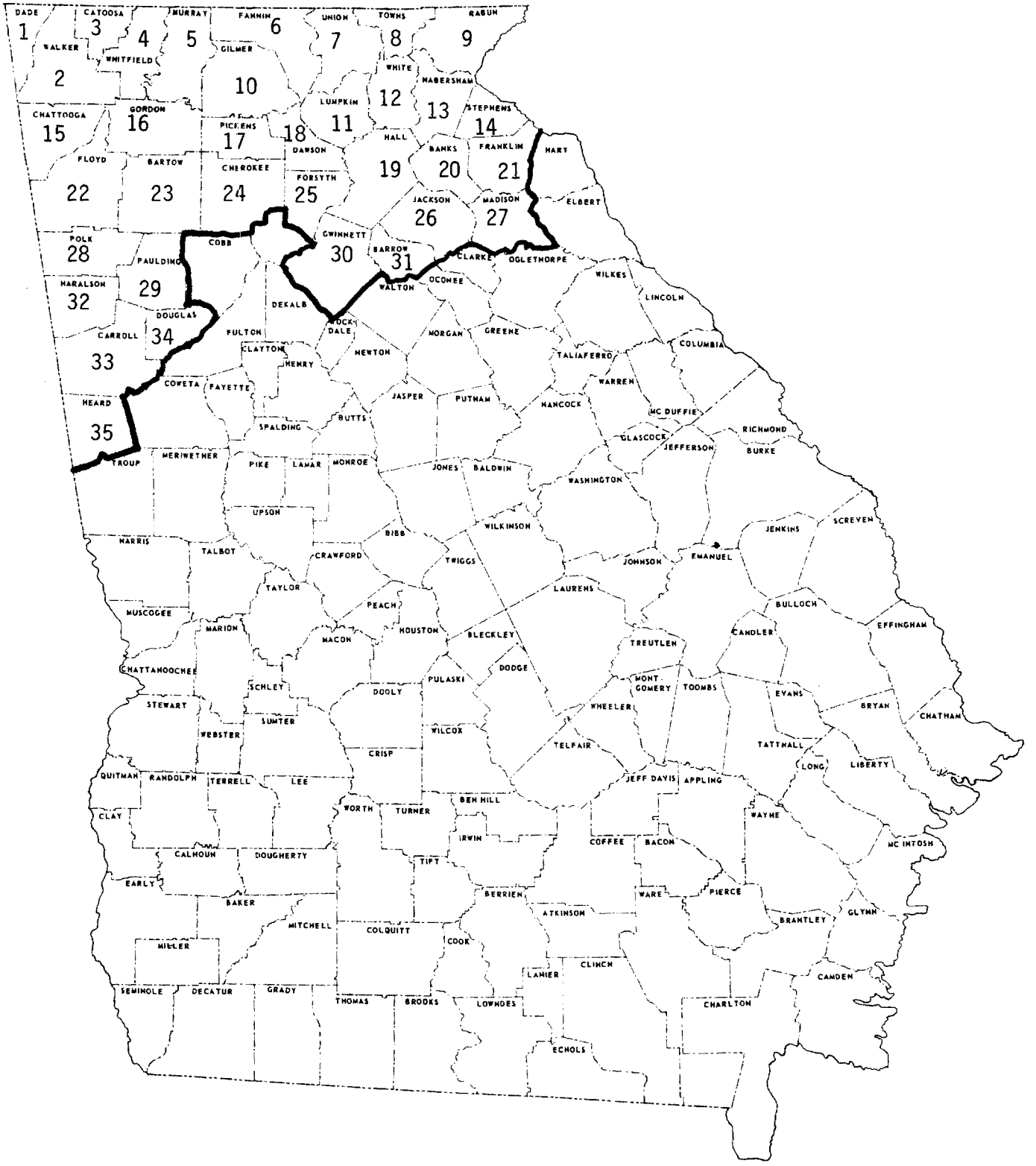

Figure B-1. Index Map of Georgia's Appalachian Region Counties

APPENDIX C

LIST OF ATTENDEES FOR CO-SITING CONFERENCE AND WORKSHOP
(held at Georgia Tech, Atlanta, Ga., on Jan. 20, 1976)

Name	Organization	Phone Number
William E. Davis	Department of Economic and Community Development, State of Tennessee, Nashville, Tennessee	(615)741-1087
Phil Whitlow	Office of Planning and Budget State of Georgia; Atlanta, Georgia	(404)656-3859
Michael A. Potterf	Appalachian Regional Commission Washington, D. C.	(202)967-3671
Darrell Gilliam	Kentucky Development Cabinet - Appalachian Regional Commission Program Frankfort, Kentucky	(502)564-7670
Anita M. Fey	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3450
Willard R. Fey	Industrial and Systems Engineering Georgia Institute of Technology Atlanta, Georgia	(404)894-2359
Lewis L. Spruill	Director, State of Georgia Energy Office Atlanta, Georgia	(404)656-5176
Jeffrey S. Tiller	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3450
Don Nicholson	Georgia Mountains Area Planning and Development Commission Gainesville, Georgia	(404)536-3431
Larry Glasco	Georgia Mountains Area and Planning Development Commission Gainesville, Georgia	(404)536-3431
Dick Cowles	Federal Energy Administration Washington, D. C.	(202)254-9755
E. P. Lomasney	Environmental Protection Agency Southeast Region Atlanta, Georgia	(404)526-5201

Name	Organization	Phone Number
Ken Kessler	North Georgia Area Planning and Development Commission Dalton, Georgia	(404)226-1672
Gunter Newsom	Atlanta Regional Commission Atlanta, Georgia	(404)522-7577
Hal Maggied	Georgia Department of Transportation Atlanta, Georgia	(404)363-7583
Warren Zurn	Federal Energy Administration Region IV Atlanta, Georgia	(404)526-5463
Hearn Lumpkin	Georgia Power Company Atlanta, Georgia	(404)522-6060
Ralph D. Carnathan	Tennessee Valley Authority Knoxville, Tennessee	(615)637-0101
Jim Corrigan	Northeast Georgia Area Planning and Development Commission Athens, Georgia	(404)548-3141
Bob Hammond	Northeast Georgia Area Planning and Development Commission Athens, Georgia	(404)548-3141
Charlie Minors	Georgia Power Company Atlanta, Georgia	(404)522-6060
John R. Gilliland	State of Georgia Bureau of Industry and Trade Atlanta, Georgia	(404)656-3580
Walter G. Belter	Energy Research and Development Administration Washington, D. C.	(301)973-4556
Lee R. Hasty	Chattahoochee-Flint Area Planning and Development Commission LaGrange, Georgia	(404)882-2956
Robert M. Mason	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3450

Name	Organization	Phone Number
Gordon R. Harrison	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3430
John E. Husted	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3630
Dalip Sondhi	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3414
Henderson C. Ward	Department of Chemical Engineering and Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3414
Jack M. Spurlock	Engineering Experiment Station Georgia Institute of Technology Atlanta, Georgia	(404)894-3414